Bedford Institute *of* Oceanography
IN REVIEW

Canada

The Bedford Institute of Oceanography (BIO) is a major oceanographic research facility, established in 1962 by the Government of Canada and located in Dartmouth, Nova Scotia, on the shore of Bedford Basin. It has grown to become Canada's largest centre for ocean research. Scientists at BIO perform research mandated by the Canadian government to provide advice and support to government decision-making on a broad range of ocean issues including sovereignty, defence, environmental protection, health and safety, fisheries, and natural resources. Environmental planning and integrated coastal and oceans management are expanding activities at the Institute.

Fisheries and Oceans Canada (DFO) is represented by five divisions within its Science Branch including the Canadian Hydrographic Service (CHS), five divisions within the Oceans, Habitat and Species at Risk Branch, the Aquaculture Coordination Office, and the Canadian Coast Guard Technical Services for technical and vessel support. Together they provide scientific knowledge and advice on issues related to climate, oceans, environment, marine and diadromous fish, marine mammals, shellfish, and marine plants. As well, they are responsible for the fish habitat management protection program, environmental assessments, integrated coastal and oceans management, species-at-risk coordination, and oceans planning initiatives.

Natural Resources Canada (NRCan) is represented by the Geological Survey of Canada (Atlantic) (GSC Atlantic), Canada's principal marine geoscience facility, and by the United Nations Convention on the Law of the Sea (UNCLOS) Program Office. NRCan's scientific research expertise focuses on marine and petroleum geology, geophysics, geochemistry, and geotechnology. The GSC Atlantic is also the source of integrated knowledge and advice on Canada's coastal and offshore landmass.

The Department of National Defence (DND) is represented by the Route Survey Office of Maritime Forces Atlantic, which supports ocean surveillance activities. In cooperation with the CHS and the GSC Atlantic, surveys are conducted in areas of the sea floor of specific interest to DND.

In support of the Canadian Shellfish Sanitation Program, the Shellfish Section of Environment Canada (EC) conducts sanitary and water quality surveys and analyzes the samples at the microbiology laboratory at BIO.

Altogether, approximately 650 scientists, engineers, technicians, managers, support staff, and contractors from a variety of disciplines work at BIO.

This review highlights research activities at the Institute, as well as activities associated with ocean-use management.

Catalogue numbers, and cover, contact, and publishing information can be found on the inside back cover.

INTRODUCTION

This report provides articles on several research themes and oceans management initiatives that were brought to completion recently, as well as short summaries of new programs. We hope you will find the articles interesting.

2008 has been a good year for the Institute on many fronts. Perhaps the most important change has been the addition of quite a few new staff to complement and stimulate our existing community. With respect to infrastructure, the new laboratory building, a facility designed to allow research on toxic chemicals in a safe manner, was completed and named in honour of Katherine Ellis, a chemical oceanographer who passed away at a young age in 1999. John Smith, her supervisor and collaborator, gave a moving speech on Kathy's important contribution to BIO. The laboratory is very attractive, with open views of Bedford Basin and surrounding grounds. The small "day boat" (*Sigma T*) was replaced by a new vessel, which is a bit larger and has greater capacity for conducting research in nearshore waters.

During 2008, BIO hosted several very successful conferences and workshops. The Annual Science Conference of the International Council for the Exploration of the Sea (ICES), held at the World Trade and Convention Centre in Halifax, was a great success, and we were all proud to have our gracious Governor General, the Right Honourable Michaëlle Jean, open the event attended by about 700 scientists from around the world.

Several of our scientists received prestigious awards. Don Gordon was the choice for the 2008 Timothy R. Parsons Award for his lifetime contributions to biological oceanography. BIO scientists including DFO's Allyn Clark, Trevor Platt, and Igor Yashayaev, and Donald Forbes of NRCan were among the group of scientists identified for the 2007 Nobel Peace Prize along with Al Gore for their contributions to the Fourth Assessment of the Intergovernmental Panel on Climate Change.

We close our comments on a nostalgic note with reference to the passing of Dr. William Cameron, the founder of the Bedford Institute of Oceanography in 1962. The idea of BIO was generated by Dr. W. E. van Steenburgh, 50 years ago during preparations for the United Nations Law of the Sea Conference in Geneva in 1958, but the task of creating the Institute was given to Dr. Cameron. He had recently graduated from the Scripps Institution of Oceanography (SIO) and was very influenced by the director of SIO, Harold Sverdrup's vision of oceanography as a multi-disciplinary institute. He would be both interested in and proud of the great work underway at BIO in 2008.

M Sinclair

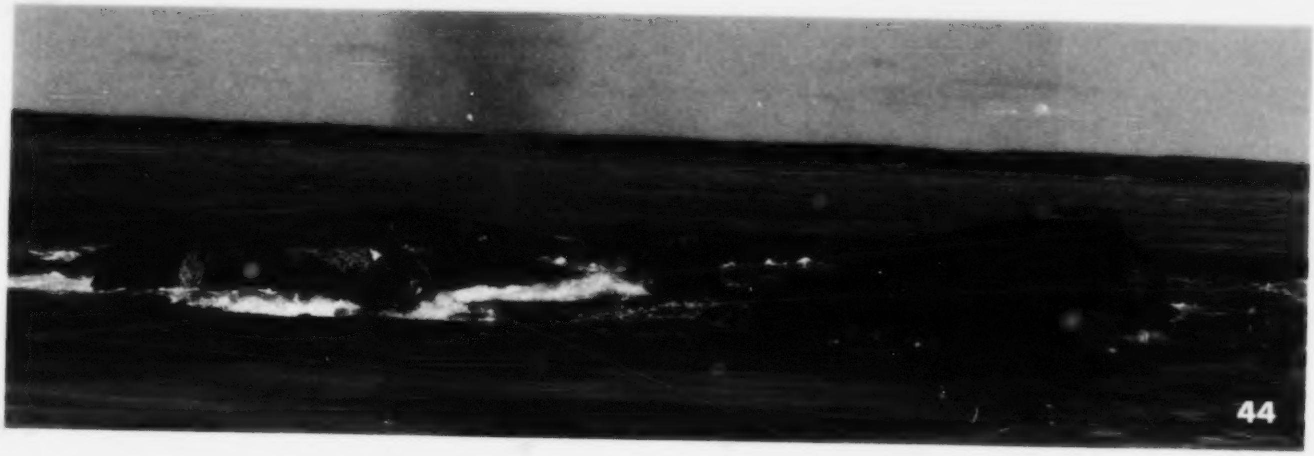
Michael Sinclair
Director, Bedford Institute of Oceanography and Director, Science, Maritimes Region
Fisheries and Oceans Canada

Stephen Locke
Director, GSC Atlantic
Natural Resources Canada

Michael Murphy
Regional Director Oceans, Habitat and Species at Risk
Maritimes Region
Fisheries and Oceans Canada

Scott Graham
Regional Director, Informatics
Fisheries and Oceans Canada

CONTENTS




55

BIO Contributes to the Development and Regulation of Canada's Ocean Renewable Energy Conversion Industry

Kenneth Lee, Peter C. Smith, and Russell Parrott

Rigid-hulled inflatable boat from CCGS *Matthew* after personnel transfer in Scots Bay, in the Bay of Fundy, Nova Scotia, where tidal power studies are underway

Recent advances in technologies for the extraction of renewable energy from the marine environment provide a new opportunity for Canada to reduce its dependence upon fossil fuels, limit the future release of greenhouse gases, and develop Canadian industrial and research expertise in an up-and-coming field.

OCEAN ENERGY RESOURCES IN CANADA

In Canada, ocean-related energy can be captured in several ways, from: waves, ocean currents, impounded tidal waters, and winds blowing over the ocean.

Canada's coastal areas experience strong and steady offshore winds (Figure 1), with the potential to provide enormous amounts of power. At present, Trillium Power Energy Inc. has a proposal for a 142-turbine farm to generate up to 710 megawatts (MW) in the Great Lakes region, and another 320-MW farm is proposed by NaiKun Wind Energy for the Queen Charlotte Islands (Haida Gwaii). While the technology for the generation of electricity from wind is well established, coastal applications will require research of construction materials to address problems of corrosion, and site-specific research to assess the ecological effects.

Existing numerical models have been used to estimate an annual mean wave power level of approximately 37,000 MW along the 1,000-m isobath (depth contour) off the Pacific coast and 146,500 MW along the Atlantic coast (Figure 2). Although the potential for wave power generation was greater for the Atlantic coast, wave energy extraction on a commercial scale may be more feasible off the

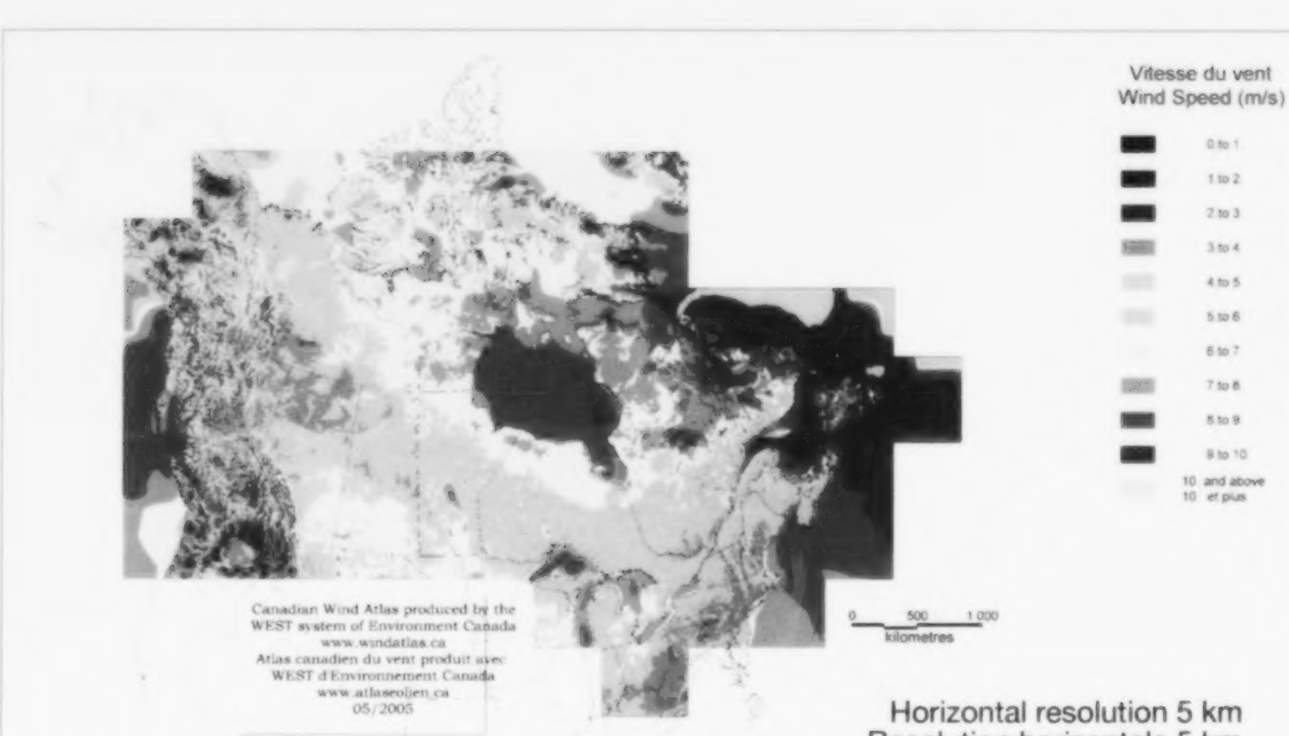


Figure 1. Average wind speeds over Canada, 50 metres above the surface (Source: Canadian Wind Resource Atlas, www.windatlas.ca)

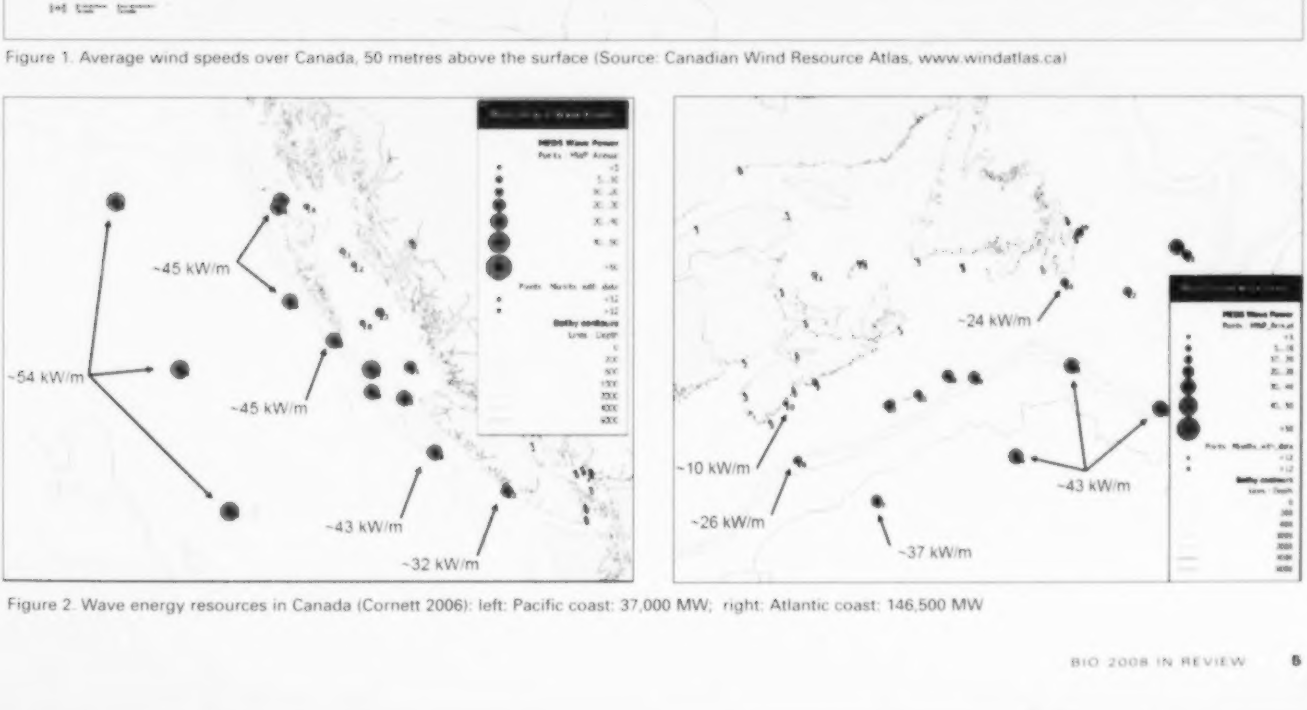


Figure 2. Wave energy resources in Canada (Cornett 2006): left: Pacific coast: 37,000 MW; right: Atlantic coast: 146,500 MW

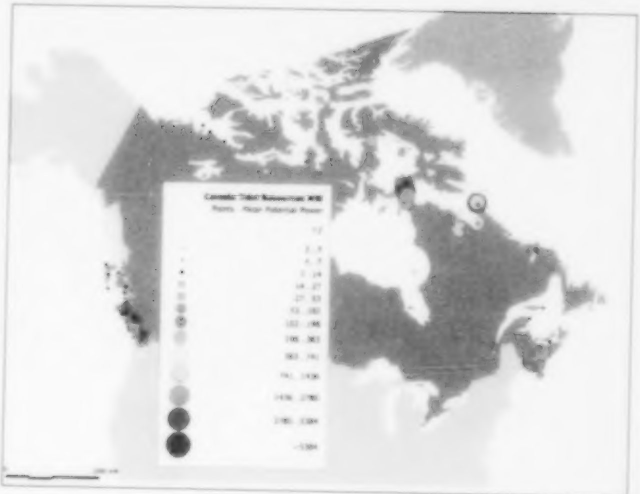


Figure 3. Tidal current resources in Canada (Source: Cornett [2006])

Pacific coast since potential sites for development are closer to shore.

More than 190 sites on the three ocean coasts of Canada have each been identified to have the potential to generate more than 1 MW of power from tidal currents (Figure 3). The output of numerical models predicted the combined potential for tidal energy to exceed 42,000 MW. While the majority of sites in Canada having more than 1 MW potential were found in British Columbia, the highest resource potential was reported to be in Nunavut, in the vicinity of Hudson Strait and Foxe Channel, and the Bay of Fundy on the Atlantic coast.

OCEAN RENEWABLE ENERGY CONVERSION TECHNOLOGIES

In recent years, more than 60 devices have been described for the recovery of energy from ocean waves. They generally fit into one of four categories:

terminators—devices oriented perpendicular to the direction of wave travel and commonly installed near or on shore to capture incoming wave energy;
attenuators—floating, articulated devices oriented parallel to the direction of wave travel that convert mechanical into electrical energy;
point absorbers—devices that utilize the rise and fall in water level at a point to compress air or hydraulic fluids, or operate pumps by the mechanical movement of buoyant subsurface structures; and
overtopping devices—various designs with ramps that create a small head difference above the surrounding sea level that is sufficient to drive a low-head turbine.

Many devices have been designed for conversion of energy from ocean currents. Most are focused on recovery of energy from strong tidal currents associated with macrotidal estuaries or passages between offshore islands. At the concept level, there has been a long history for the development of Tidal In-Stream Energy Converters (TISEC) which extract the *kinetic energy* of fast-flowing tidal waters. For example, the Davis vertical-axis turbine (based on the Darrieus wind turbine) was designed by Canada's National Research Council more than 30 years ago. Today, the most established technologies for commercial development are based on horizontal-axis designs that can be scaled up in size in the same way as wind turbines.

Four TISEC technologies are currently under evaluation within Canada:

Figure 4. Clean Current™ Turbine – image courtesy of Clean Current Turbine

1) The Clean Current™ Turbine, a Canadian-made, horizontal-axis turbine has a duct that increases the velocity of water flow (Figure 4). Having an open centre, it is classified as a rim-generator. A 65-kW device has been under evaluation at Race Rocks, near Victoria, Vancouver Island in preparation for a commercial-scale development at the site. A larger model generating <2.2 MW is being prepared for installation at the Fundy tidal test facility in Minas Passage, Nova Scotia.

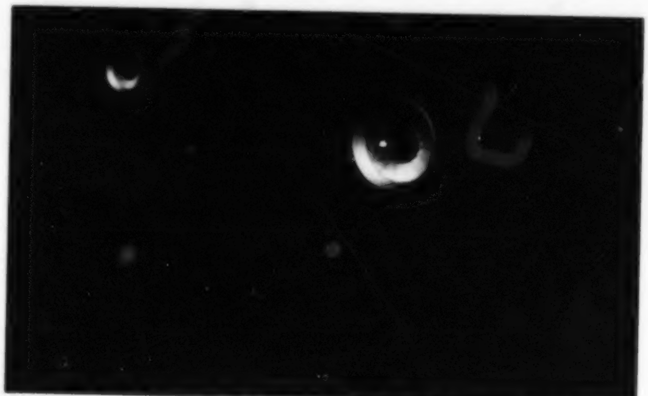


Figure 5. Open Centre™ Turbine – image courtesy of Nova Scotia Power Incorporated

2) The Open Centre Turbine™ (6-m diameter, 250 kW) (Figure 5) by Open Hydro Incorporated has been tested with connections to a grid since May 2008 at the European Marine Energy Centre in Scotland. A 12-m-diameter version of this bottom-mounted device yielding 2 MW will be installed at the Fundy tidal test facility in Minas Passage, Nova Scotia.

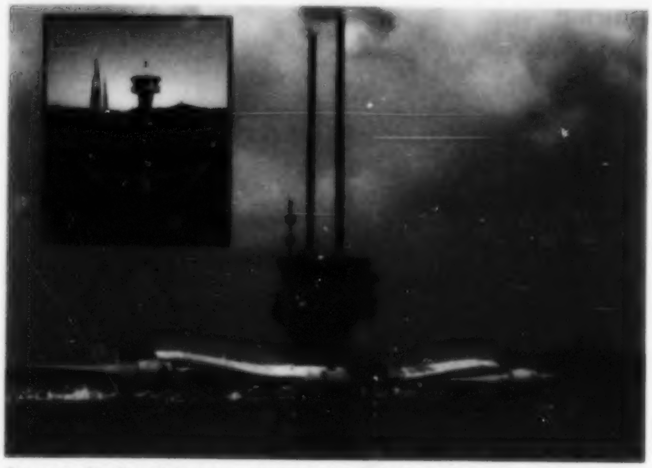


Figure 6. SeaFlow™ Turbine - photo courtesy of Dr. I.J. Stevenson, provided by Marine Current Turbines Ltd.

3) The SeaFlow™ and SeaGen™ turbines represent the most advanced TISEC devices from Marine Current Turbines in the United Kingdom. This company has developed a number of horizontal-axis designs involving two or three propeller blades (Figure 6). A SeaGen™ turbine facility is currently under construction in Strangford Lough, Northern Ireland and is expected to yield 2.2 MW. Marine Current Turbines will deploy a unit in the Bay of Fundy, Nova Scotia under a partnership with Minas Basin Pulp and Power Company.

4) Verdant Power Canada is commencing a second project in the St. Lawrence River near Cornwall, Ontario to demonstrate a redesigned Free Flow Turbine that is expected to be incorporated into a commercial array capable of yielding up to 15 MW. The first deployment of Verdant Power's Free Flow Turbine in the East River, New York, generated less than 65 kW.

Conventional tidal power approaches of the last century generally focused on barrage-based developments based on the conversion of the *potential* energy of water that has been impounded at a level above that of the surrounding sea. While the yield may be greater, environmental concerns have generally been important deterrents to their development. The last barrage tidal generating station built in the western hemisphere was at Annapolis Royal, Nova Scotia in 1980-1984.

A modern variant of the barrage is the proposed construction of tidal lagoons in macrotidal estuaries including the Bay of Fundy, Nova Scotia. Since the lagoons may be detached from the shoreline, they may avoid some of the concerns raised by barrages, while enabling the capture of relatively large quantities of power from the potential energy of the impounded water. However, there remain several important environmental implications that have yet to be fully assessed, such as habitat loss, fish entrainment, and sedimentation.

DEVELOPMENT OF OCEAN RENEWABLE ENERGY IN THE BAY OF FUNDY

The Bay of Fundy is an estuarine embayment with a resonant period of about 13 hours. This resonance is close to the Atlantic Ocean's domi-

Figure 7. Shaded relief image was generated from multibeam bathymetry and LiDAR data in Minas Passage, the site of proposed in-stream tidal power generation in the Bay of Fundy. Large sandwave fields, called Banner banks, are visible near the promontories at Cape D'Or (A) and Cape Split (B). As a direct result of the multibeam survey data, active and mobile areas in the wake regions of Black Rock (C) and Cape Sharp (D) were deemed to be unsuitable for turbine placement.

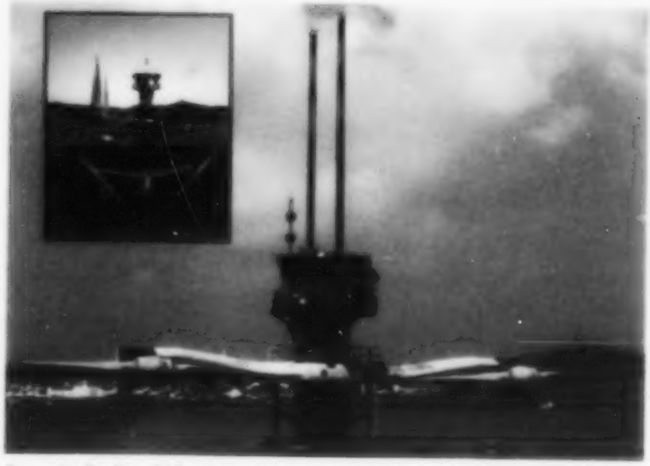


Figure 6. SeaFlow™ Turbine - photo courtesy of Dr. I.J. Stevenson, provided by Marine Current Turbines Ltd.

3) The SeaFlow™ and SeaGen™ turbines represent the most advanced TISEC devices from Marine Current Turbines in the United Kingdom. This company has developed a number of horizontal-axis designs involving two or three propeller blades (Figure 6). A SeaGen™ turbine facility is currently under construction in Strangford Lough, Northern Ireland and is expected to yield 1.2 MW. Marine Current Turbines will deploy a unit in the Bay of Fundy, Nova Scotia under a partnership with Minas Basin Pulp and Power Company.

4) Verdant Power Canada is commencing a second project in the St. Lawrence River near Cornwall, Ontario to demonstrate a redesigned Free Flow Turbine that is expected to be incorporated into a commercial array capable of yielding up to 15 MW. The first deployment of Verdant Power's Free Flow Turbine on the East River, New York, generated less than 85 kW.

Conventional tidal power approaches of the last century generally focused on barrage-based developments based on the conversion of the potential energy of water that has been impounded at a level above that of the surrounding sea. While the yield may be greater, environmental concerns have generally been important deterrents to their development. The last barrage tidal generating station built in the western hemisphere was at Annapolis Royal, Nova Scotia in 1980-1984.

A modern variant of the barrage is the proposed construction of tidal lagoons in macrotidal estuaries including the Bay of Fundy, Nova Scotia. Since the lagoons may be detached from the shoreline, they may avoid some of the concerns raised by barrages, while enabling the capture of relatively large quantities of power from the potential energy of the impounded water. However, there remain several important environmental implications that have yet to be fully assessed, such as habitat loss, fish entrainment, and sedimentation.

DEVELOPMENT OF OCEAN RENEWABLE ENERGY IN THE BAY OF FUNDY

The Bay of Fundy is an estuarine embayment with a resonant period of about 13 hours. This resonance is close to the Atlantic Ocean's domi-

Figure 7. Shaded relief image was generated from multibeam bathymetry and LiDAR data in Minas Passage, the site of proposed in-stream tidal power generation in the Bay of Fundy. Large sandwave fields, called Banner banks, are visible near the promontories at Cape D'Or (A) and Cape Split (B). As a direct result of the multibeam survey data, active and mobile areas in the wake regions of Black Rock (C) and Cape Sharp (D) were deemed to be unsuitable for turbine placement.

Figure 8. Shaded relief image, looking northwest, was generated from multibeam bathymetry data of part of the upper Bay of Fundy centred near 45° 01'N, 65° 33'W. Image shows large deposits of horse mussels, seen in the foreground as wrinkles. Depth is colour-coded from 45 to 90 metres, as shown in the attached colour bar. Red areas are sand waves and dunes.

nant lunar tide of 12 hours and 25 minutes, and results in the largest recorded tides in the world, with a range that increases from about 4 m at the mouth of the Bay to a maximum of 17 m at the head of the Bay. These extremely large tides generate strong current velocities that exceed 4.5 m s^{-1} (metres per second) in restricted narrow passages at various points in the Bay and as long ago as 1910 have been the focus of plans to harness tidal power. In the mid-1970s, serious consideration was given to the development of tidal power within the Bay of Fundy. These deliberations led to the installation of a tidal power barrage across the mouth of the Annapolis River in 1984. Further development of a barrage system within the Bay of Fundy has not been considered following the identification of potential far-field effects associated with changes in the estuary's morphology, alterations in fish migration, and direct and indirect effects on fish, birds, and mammals.

With advances in marine technology, the recovery of ocean renewable energy has recently shifted to the exploitation of tidal kinetic energy (currents) using TISEC devices. In 2005, Electric Power Research Institute Inc. (EPRI) published an evaluation of the TISEC potential in Nova Scotia that identified the Minas Passage region (Figure 7) as the most promising site for development based on energy resource levels, bottom conditions, proximity to the existing electric power grid, and suitability for onshore facilities.

Nova Scotia's 2009 Energy Strategy sets a new target of at least 25% renewable electricity supply by 2020. Ocean renewable energy from the Bay of Fundy is expected to contribute towards the realization of this target level. The vision for implementing this technology in the Bay of Fundy is to:

1) choose an optimal location(s) based on assessments of resource potential, costs, and minimal impacts;
2) install a small number of pilot demonstration turbines for engineering and other evaluations; and
3) expand the project to a commercial scale with generating capacity of 200-300 MW, or roughly 15% of the total mean depth-averaged power available.

A consortium of private companies (Clean Current Turbines, Open Hydro, and Marine Current Turbines) will install and test three demonstration units (Figures 4, 5, and 6) at selected sites in the northwest corner of Minas Passage near Black Rock. The first unit is scheduled for deployment in the fall of 2009.

SITE CHARACTERIZATION IN SUPPORT OF TISEC DEVICE DEPLOYMENTS

Canadian vessels equipped with multibeam bathymetry systems have been collecting data in the Bay of Fundy since 1992. In 2006, the Geological Survey of Canada, in conjunction with the Canadian Hydrographic Service and several universities, started a three-year program to map the Bay of Fundy. To date, about 12,500 km² of multibeam bathymetry data have been collected in the Bay. Sub-bottom profiler data were collected simultaneously to provide information on the character and thickness of the sediments on the seafloor. Various points in the Bay are presently being studied to determine their suitability to be harnessed for electrical power generation.

Data collected during these studies from current meters, suspended sediment sensors, and time-lapse photographs will be used to provide information on seafloor properties and the dynamics of the water column, and in conjunction with the improved bathymetry data, will be used to improve the resolution and accuracy of tide and current prediction models.

The broad intertidal zone in the Bay of Fundy presents a challenge to collection of marine geophysical and bathymetry data. Traditionally, this area has not been surveyed due to the significant time requirements and inherent danger involved in operating vessels in coastal areas that dry between tides. In conjunction with the College of Geographical Sciences (COGS) in Lawrencetown, these areas were surveyed using airborne terrestrial laser known as LiDAR (Light Detection And Ranging), that also provides very high-resolution elevation models. The combination of these techniques enables the generation of a continuous map of the marine, inter-tidal, and terrestrial areas. The data were collected during an extreme low tide to provide detailed elevation measurements of the inter-tidal areas. LiDAR surveys performed between 2000 and 2007 mapped about 4000 km² of the surrounding land. Multibeam bathymetry data will be collected during high tides to provide a seamless digital elevation model across the inter-tidal zone. The LiDAR data will be used to evaluate the on-shore topography to select the best route for power transmission cables.

Some key findings from the recent surveys include:

- Deep tidal-scour channels are present in several areas. About 4 km³ of material have been eroded from the Minas Passage, resulting in a seafloor that is mainly exposed bedrock with very little sediment cover in the areas selected for the initial tests for in-stream tidal power generation.
- Sediments are found in the nearshore areas and will have to be traversed by underwater transmission cables connecting with the offshore generators. The multibeam bathymetry data shown in Figure 7 were used as the basis for preliminary project development and to plan the more detailed engineering surveys required to site the turbines.
- Large glacial landforms are present throughout the bay and may provide suitable substrates for fish and shellfish.
- Strong tidal currents are reworking sediments deposited during the last glacial period; reworked material has accumulated in fields of sand waves whose morphology and extent have been precisely delineated for the first time (Figure 8).
- Migration of large sand waves (1 km wide and 21 m high) has been observed in repetitive surveys.

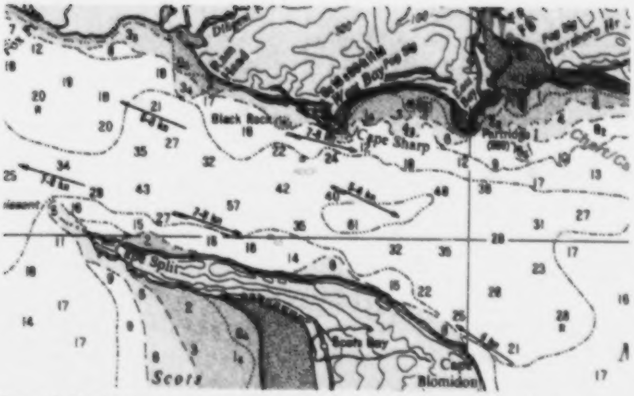


Figure 9. Navigation chart for Minas Passage showing locations of both historical (1965) and recent DFO (ADCP) moorings

- Extensive horse mussel reefs have been found at many locations throughout the Bay. To-date, approximately 1,500 of the reefs with an average length of 258 m have been mapped. Reefs with lengths up to 2 km have been discovered.

ASSESSMENT OF POTENTIAL ENVIRONMENTAL IMPACTS

In 2007, the Nova Scotia Department of Energy commissioned a Strategic Environmental Assessment (SEA) focusing on tidal energy development in the Bay of Fundy. Completed in April 2008, the SEA contained 29 specific recommendations, including:

- restriction of commercial application until proponents demonstrate that there will be no significant adverse effects on the fundamental dynamics of the Bay of Fundy (energy flow, erosion, deposition) or biological processes and resources,
- minimization of adverse impacts on fisheries and aquaculture in the Bay, and
- development of a collaborative research program for study of marine renewable energy extraction from the Bay.

In response to the SEA, scientists from BIO are undertaking to measure current and sediment concentration in the Minas Passage to assist with evaluating resource potential, establishing a baseline data set from the area, and developing and validating high-resolution hydrodynamic and sediment transport models in the upper Bay. Ongoing research efforts are supported jointly by DFO, the ecoEnergy Technology Initiative program for renewable energy under NRCan, and Offshore Energy Environmental Research, established by the Nova Scotia Department of Energy.

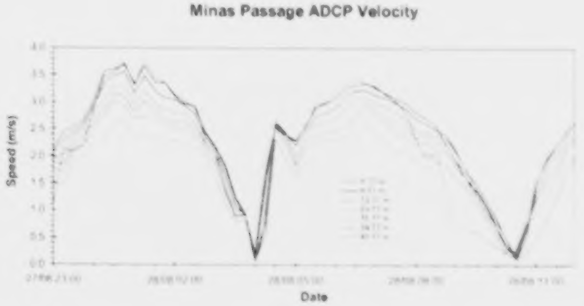


Figure 10. Observed ADCP speed records in Minas Passage at selected depths

OBSERVATIONS AND MODELING OF PHYSICAL PARAMETERS

As part of the present study, DFO scientists deployed a single, bottom-mounted Acoustic Doppler Current Profiler (ADCP) mooring at a depth of roughly 50 m on the northern side of the Passage off Cape Sharp (Figure 9) in August-September 2007. During both the flood and ebb phases of the tidal cycle, the flow is strong and highly aligned throughout the water column, with maximum currents near 4 m/sec (~8 knots, see Figure 10). The residual flow (the average current after removing tidal constituents) is weak (<0.16 m/sec) and directed across the passage, perpendicular to the flood-ebb direction. Physical data such as these will be used to validate new and improved hydrodynamic models, and ultimately help to constrain the more complicated sediment dynamics models. These advances should lead to significantly better estimates of near-field and far-field environmental impacts of TISEC.

POTENTIAL ENVIRONMENTAL IMPACTS OF TISEC

The scientific consensus at this point is that the presence of just three demonstration turbines in the Minas Passage, each extracting in the order of 1 MW of energy, should have little detectable or irreversible effect on either the sediment distribution or living marine resources of the area. However, a commercial-scale venture, potentially composed of as many as 300 devices, may have a significant impact on the near- and far-field benthic conditions as well as the plentiful and valuable marine animals that pass through the area. Use of physical and geophysical data to improve existing hydrodynamic and sediment-dynamic models will lead to significantly better estimates of potential near-field and far-field impacts of TISEC.

NEAR-FIELD BENTHIC IMPACTS

In the vicinity of benthic obstructions, mobile bedforms, which may be created due to sediment movement and deposition in response to current flow around an obstruction, are expected to modify the benthic habitat in an area equivalent to 1-2 times the diameter of the obstruction. However, the area and magnitude of such features, whether natural or man-made, depend strongly on bottom type and the availability of fine-grained sediment. A seafloor comprised of bedrock, for example, will show little or no impact compared to sandy or silty bottoms. Therefore in the deep regions in the Minas Passage where the seafloor has been scoured to the bedrock the presence of benthic turbines or other such devices should have little or no impact on sediment transport. However, the active areas on either side of Black Rock and near the coast are composed of cobble with wave-like features that are mobile and propagate through the regime and are therefore more susceptible to sediment migration caused by obstructions. In recognition of this fact, all three demonstration units in Minas Passage will be placed on the bedrock to the west of Black Rock in roughly 50-m depths.

FAR-FIELD BENTHIC IMPACTS

In near-resonant, highly-nonlinear hydrodynamic systems such as the Bay of Fundy-Gulf of Maine, changes in one part of the domain (e.g.,

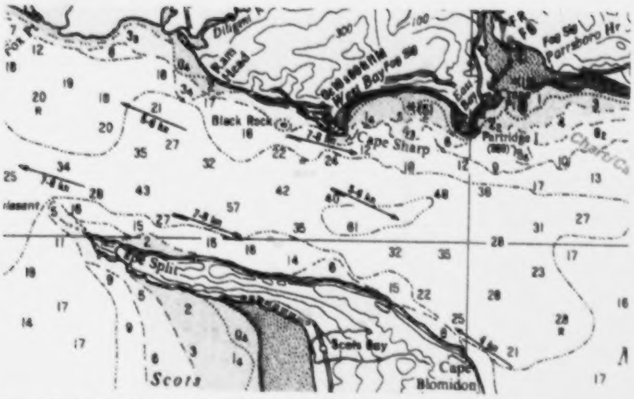


Figure 9. Navigation chart for Minas Passage showing locations of both historical (1965) and recent DFO (ADCP) moorings

- Extensive horse mussel reefs have been found at many locations throughout the Bay. To-date, approximately 1,500 of the reefs with an average length of 258 m have been mapped. Reefs with lengths up to 2 km have been discovered.

ASSESSMENT OF POTENTIAL ENVIRONMENTAL IMPACTS

In 2007, the Nova Scotia Department of Energy commissioned a Strategic Environmental Assessment (SEA) focusing on tidal energy development in the Bay of Fundy. Completed in April 2008, the SEA contained 29 specific recommendations, including:

- restriction of commercial application until proponents demonstrate that there will be no significant adverse effects on the fundamental dynamics of the Bay of Fundy (energy flow, erosion, deposition) or biological processes and resources,
- minimization of adverse impacts on fisheries and aquaculture in the Bay, and
- development of a collaborative research program for study of marine renewable energy extraction from the Bay.

In response to the SEA, scientists from BIO are undertaking to measure current and sediment concentration in the Minas Passage to assist with evaluating resource potential, establishing a baseline data set from the area, and developing and validating high-resolution hydrodynamic and sediment transport models in the upper Bay. Ongoing research efforts are supported jointly by DFO, the ecoEnergy Technology Initiative program for renewable energy under NRCan, and Offshore Energy Environmental Research, established by the Nova Scotia Department of Energy.

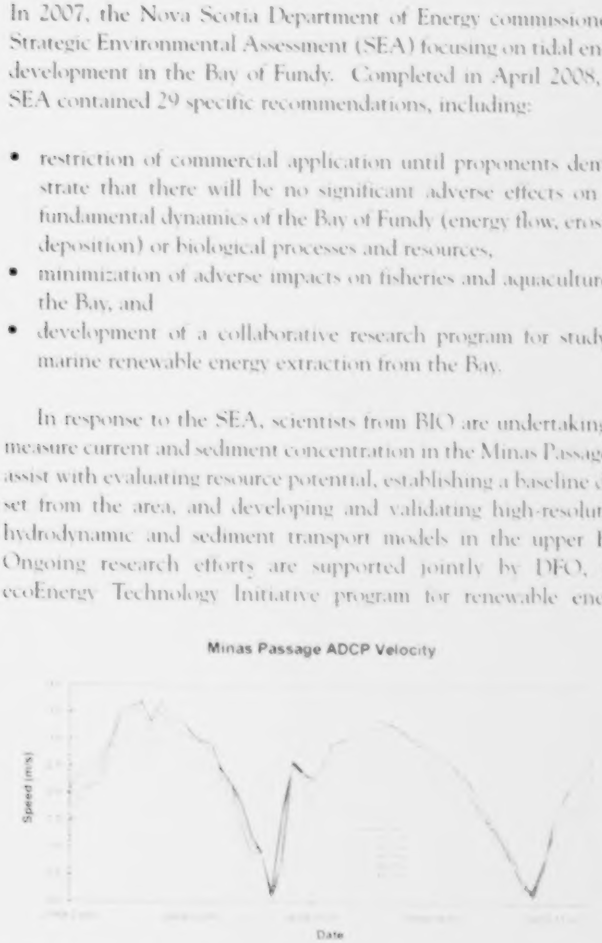


Figure 10. Observed ADCP speed records in Minas Passage at selected depths

OBSERVATIONS AND MODELING OF PHYSICAL PARAMETERS

As part of the present study, DFO scientists deployed a single, bottom-mounted Acoustic Doppler Current Profiler (ADCP) mooring at a depth of roughly 50 m on the northern side of the Passage off Cape Sharp (Figure 9) in August-September 2007. During both the flood and ebb phases of the tidal cycle, the flow is strong and highly aligned throughout the water column, with maximum currents near 4 m/sec (~8 knots, see Figure 10). The residual flow (the average current after removing tidal constituents) is weak (<0.16 m/sec) and directed across the passage, perpendicular to the flood-ebb direction. Physical data such as these will be used to validate new and improved hydrodynamic models, and ultimately help to constrain the more complicated sediment dynamics models. These advances should lead to significantly better estimates of near-field and far-field environmental impacts of TISEC.

POTENTIAL ENVIRONMENTAL IMPACTS OF TISEC

The scientific consensus at this point is that the presence of just three demonstration turbines in the Minas Passage, each extracting in the order of 1 MW of energy, should have little detectable or irreversible effect on either the sediment distribution or living marine resources of the area. However, a commercial-scale venture, potentially composed of as many as 300 devices, may have a significant impact on the near- and far-field benthic conditions as well as the plentiful and valuable marine animals that pass through the area. Use of physicall and geophysical data to improve existing hydrodynamic and sediment-dynamic models will lead to significantly better estimates of potential near-field and far-field impacts of TISEC.

NEAR-FIELD BENTHIC IMPACTS

In the vicinity of benthic obstructions, mobile bedforms, which may be created due to sediment movement and deposition in response to current flow around an obstruction, are expected to modify the benthic habitat in an area equivalent to 1-2 times the diameter of the obstruction. However, the area and magnitude of such features, whether natural or man-made, depend strongly on bottom type and the availability of fine-grained sediment. A seafloor comprised of bedrock, for example, will show little or no impact compared to sandy or silty bottoms. Therefore in the deep regions in the Minas Passage where the seafloor has been scoured to the bedrock the presence of benthic turbines or other such devices should have little or no impact on sediment transport. However, the active areas on either side of Black Rock and near the coast are composed of cobble with wave-like features that are mobile and propagate through the regime and are therefore more susceptible to sediment migration caused by obstructions. In recognition of this fact, all three demonstration units in Minas Passage will be placed on the bedrock to the west of Black Rock in roughly 50-m depths.

FAR-FIELD BENTHIC IMPACTS

In near-resonant, highly-nonlinear hydrodynamic systems such as the Bay of Fundy-Gulf of Maine, changes in one part of the domain (e.g.,

Figure 11. Sediment sampling array deployed in tidal channel of the Avon River, Windsor, Nova Scotia – photo courtesy of Dr. Danika van Proosdij, Department of Geography, Saint Mary's University

geometry, energy flux) can have disproportionately large responses and significant environmental impacts in distant parts of the domain. Indeed, a numerical model has demonstrated that a tidal barrage placed across the Minas Basin would increase the tidal amplitude in Boston, Massachusetts by an estimated 15 cm, while reducing it in the outer Bay of Fundy. Similarly, alterations to current patterns from construction projects in the upper Bay (e.g., Windsor and Petitcodiac causeways in 1970 and 1968, respectively) have resulted in massive, unanticipated changes in the sedimentation regime, particularly in shallow areas such as macrotidal flats and freshwater tributaries. Overall, the sediment behaviour in the upper Bay of Fundy is not well understood or predicted. Thus, there is a strong need to develop and validate a sediment dynamics model for the Bay of Fundy-Gulf of Maine to complement the hydrodynamic model and help to provide accurate forecasts of environmental consequences.

FISH BEHAVIOUR IN THE VICINITY OF ACTIVE TURBINES

Another possible consequence of the presence of in-stream tidal energy devices is significant fish mortality due to fish swimming into and striking the moving blades of turbines during massive migrations up and down the Passage. To address this question, scientists from the St. Andrews Biological Station and BIO have initiated a study to determine whether multibeam sonar technology (Simrad MS 2000) could be used to detect and monitor the presence and behaviour of fish in the vicinity of active TISEC turbines placed in a turbulent environment such as the Minas Passage. Central to the study is the fact that both single and multibeam technologies are very sensitive to suspended debris and entrained air bubbles which in turn can severely limit fish detection capability by producing a backscattering noise background or direct acoustic extinction.

Proof-of-concept studies for the Simrad MS 2000 bathymetry have been conducted in the Western Passage off St. Andrews, New Brunswick, and Minas Passage during November 2008 and January 2009, respectively. Although these results are presently being analyzed and evaluated (Melvin et al., 2009), it is clear that schools of fish and individual items (e.g., submerged ice, large mammals) are more easily identified in the less turbulent environment of Western Passage. Nevertheless, acoustic visibility in the Minas Passage is generally adequate in the bottom 30% of the water column, particularly in the deeper parts of the Passage and near slack tide.

NEXT STEPS

Plans for the future include both modeling and field work:

- Ten ADCP moorings will be deployed, five each in Minas Passage and Minas Basin, for the purpose of understanding and modeling the hydrodynamics and related sediment dynamics in both summer and winter.
- The hydrodynamics model will be carefully validated against both moored and transect ADCP data, especially in terms of the relatively weak nonlinear tidal constituents which are important to sediment dynamics and transport.
- A comprehensive sediment dynamics model, including effects of fluid mud, will be developed and tested against observations.
- Detailed deposition and erosion observations will be made in a tidal creek near Starr's Point over a spring-neap cycle of the dominant semi-diurnal tide. The natural variation in tidal energy should serve as a proxy for energy extraction from the system by TISEC development. Field observations include acoustic Doppler current velocity measurements, water column sediment concentration from optical backscatterance and direct sampling, and laser range detection of the mud surface for continuous measures of accretion/erosion (e.g., Figure 11).
- Regarding the detection of fish behaviour, the capabilities of alternative technologies to the Simrad MS 2000 (e.g., the Coda Octopus system) will be evaluated. The idea of mooring an upward-looking, split-beam system in the vicinity of an active turbine will also be explored.

DEVELOPMENT OF POLICY AND REGULATIONS FOR OCEAN RENEWABLE ENERGY

There is an immediate need for sound, science-based, national policies and regulations to ensure the development of offshore renewable energy will occur in an environmentally and socially responsible manner. The generic environmental and socio-economic issues associated with the development of ocean renewable energy include:

- effects of changes in the energy of water movements
- interactions with coastal sedimentary processes
- interactions with marine life
- atmospheric and oceanic emissions
- effects of electromagnetic fields
- installation and decommissioning effects
- conflicts over space with other uses
- visual effects.

As illustrated by BIO's preliminary studies in the Bay of Fundy, physical and biological processes are intertwined within coastal environments. Consequently, energy extraction at one point in a coastline might have important large-scale, indirect effects on more distant coastal ecosystems. Such *far-field* effects have, in the past, often fallen outside the scope of environmental impact assessments (EIA), which were usually focused on regional and/or *near-field* implications to address regulatory compliance. Thus, in determining the appropriate strategy to address environmental issues of marine energy extraction, it may be necessary to distinguish between the research that is needed to assess the risk of specific site and technology developments, which might be the responsibility of propo-

nents through EIA processes, and the more generic research at an integrated ecosystem-based management level that should be the responsibility of government-funded research.

Canada's theoretical and practical experience for monitoring the environmental impacts of ocean renewable energy conversion is extremely limited. As it is a new industry, there have been no studies on the long-term, near- and far-field effects of commercial-scale TISEC operations. To ensure that the future development of these technologies is consistent with current ecological and species-at-risk conservation priorities, it is essential to improve our understanding of the potential environmental implications that may be encountered. DFO's Centre for Offshore Oil, Gas and Energy Research (COOGER) is currently preparing a comprehensive review of the current state of knowledge about environmental impacts and their mitigation options for wave and tidal power development in Canada. The aim of this review is to summarize what is known and uncertain, and to identify key research required to provide the scientific support necessary for the development of policies and regulations for the Canadian offshore renewable energy conversion industry.

BIBLIOGRAPHY

Baker, C., J. Walbancke, and P. Leach. 2006. Tidal lagoon power generation scheme in Swansea bay. Report to the Department of Trade and Industry and the Welsh Development Agency. 50 pp.

Bedard, R., M. Previsic, O. Siddiqui, G.. Hagerman, and M. Robinson. 2005. Survey and characterization – Tidal in-stream energy conversion devices. EPRI Report EPRI-TP-004-NA. 131 p.

Bay of Fundy Tidal Power Review Board. 1977. Reassessment of Fundy tidal power. Minister of Supply and Services Canada. Ottawa, 516 pp.

Cornett, A. (2006). Inventory of Canada's marine renewable energy resources. National Research Council Canada, Canadian Hydraulics Centre (NRC-CHC) Technical Report-041, Ottawa, ON, Canada.

Daborn, G. (ed.) 1977. Fundy tidal power and the environment. Acadia University Inst. Publ. No. 28, 304pp.

Dadswell, M.J., R.A. Rulifson, and G.R. Daborn. 1986. Potential impact of large scale tidal power developments in the upper Bay of Fundy on fisheries resources of the Northwest Atlantic. Fisheries 11: 26-35.

Dadswell, M.J. and R.A. Rulifson. 1994. Macrotidal estuaries: a region of collision between migratory marine animals and tidal power development. Biol. J. Linnean Soc., 51, 93-113.

Dupont, F., C.G. Hannah, and D.A. Greenberg. 2005. Modelling the sea level in the Upper Bay of Fundy, Atmosphere-Ocean, 43(1), 33-47.

EPRI, 2005. Survey and Characterization – Tidal In-Stream Energy Conversion Devices. Electric Power Research Institute Inc. report TP-004-NA prepared by Electric Power Research Institute, EPRI solutions, Virginia Polytechnic Institute and State University, Mirko Previsic Consulting, National Renewable Energy Laboratory. 131 pp.

Friends of the Earth. 2004. Tidal lagoons.
www.foe.co.uk/campaigns/climate/case studies/tidal_lagoons.html

Garrett, C. 1972. Tidal resonance in the Bay of Fundy and Gulf of Maine. Nature, v.238, 441-443.

Garrett, C. 1974. Normal modes of the Bay of Fundy and Gulf of Maine. Can. J. Earth Sci., 11, 549-556.

Gordon, D.C. Jr. and M.J. Dadswell. 1984. Update on the marine environmental consequences of tidal power development in the upper reaches of the Bay of Fundy. Can. Tech. Rep. Fish. Aquat. Sci., No. 1256, 686 pp.

Greenberg, D.A. 1987. Modeling tidal power. Scientific American, v.255(11), 128-131.

Hagerman, G. 2004. Offshore wave power in the US: environmental issues. EPRI Report E21 Global EPRI – 007-US. 29 pp.

Jacques Whitford. 2008. Background report for the strategic environmental assessment for Bay of Fundy tidal power development. Report for Offshore Energy Environmental Research Association. 273 p.

Melvin, G.D., N.A. Cochrane, and P. Fitzgerald. 2009. Evaluation of single and multi-beam sonar technology for water column target detection in an acoustically noisy environment. Can. Tech. Rep. Fish. Aquat. Sci. 2840, in press.

Minerals Management Service. 2006b. Technology white paper on ocean current energy potential on the US Outer Continental Shelf. Report for Renewable Energy and Alternate Use Program, USDI. 7 p.

Previsic, M., R. Bedard, and G. Hagerman. 2004. Offshore wave energy conversion devices. EPRI Report E21-EPRI-WP 004-US-Rev 1. 52 pp.

Thurston, H. 1990. Tidal Life. A Natural History of the Bay of Fundy. Nimbus Publishing Ltd. Halifax, NS.

Verdant Power Canada. 2006. Technology evaluation of existing and emerging technologies: water current turbines for river applications. Report prepared for Natural Resources Canada. 48 pp.

ACKNOWLEDGEMENTS

The authors would like to thank Gary Melvin and Norm Cochrane for their contribution describing their fish behaviour "proof-of-concept" study; Tim Milligan for his expertise on sediment studies; David Greenberg and Richard Karsten for the development and application of models; and Keir Colbo for current analysis and interpretation.

Geoscience Technology for Management and Economic Development in the Bay of Fundy

Jonathan Griffin

The Canadian Hydrographic Service and the Geological Survey of Canada, with university partners, are undertaking to map the Bay of Fundy. Geoscience for Management and Economic Development in the Bay of Fundy is a national project in the Geoscience for Oceans Management program. Canada's Oceans Action Plan has identified the Bay of Fundy as a priority area for seabed mapping as it supports the four pillars of Canada's Oceans Strategy (2002):

- International Leadership, Sovereignty and Security
  The Bay of Fundy shares an international boundary with the US.
- Integrated Oceans Management for Sustainable Development
  The area has significant inshore fisheries and aquaculture sites.
- Oceans Health
  Mapping addresses the priorities of habitat maps, current and tide models for circulation within the bay, and recharting of whale routes.
- Oceans Science and Technology
  Surveys assist with the selection of an experimental tide turbine.

The article "New Multibeam Bathymetry Surveys in the Bay of Fundy" in *Bedford Institute of Oceanography 2007 in Review*, focused on the geologic findings and the potential to support tidal power research. This article highlights the technology used for the seabed mapping.

SEABED DATA ACQUISITION

The 2008 research was conducted from four survey platforms: the hydrographic vessel, CCGS *Matthew*, its two launches the *Plover* and *Pipit*, and the CCGS *F. G. Creed*. The 2008 survey in the Bay of Fundy added another 22,800 km of data to the overall Bay of Fundy survey data set. As part of their field camp aboard the launch *Heron*, the Ocean Mapping Group of the University of New Brunswick (UNB) in Fredericton contributed 10 days of surveying.

The technology used aboard these vessels to sound the depths is termed *multibeam*. A beam of acoustic energy is transmitted into the

CCGS *Matthew*

CCGS *Frederick J. Creed*

Canadian Survey Launches *Plover* and *Pipet*

Operator console aboard the CCGS *Matthew* during multibeam acquisition

water column beneath the vessel. The resultant echo is received through a transducer that listens in a wide beam across track (side to side), and very narrow beam along track (fore and aft). Further processing splits this thin slice into a series of distinct beams, each between ½ and 1 degree in width and breadth. A bottom-detection algorithm determines which part of the received time series data within each beam is seabed, based on the strength of amplitude or degree of phase shift of the returned echo. The received time that corresponds to this stronger target (usually the seabed) is converted to a range using the speed of propagation of sound through seawater (measured from sound velocity profiles taken in situ). These ranges are then converted to a depth, after applying vessel motion (heave pitch and roll), vessel position (latitude and longitude), and vertical offset (vessel draft, transducer depth, and tide).

This process happens two to ten times a second. The various swath systems can return between 160 and 400 beams in a single swath (or ping). A multibeam platform can return more soundings in a minute than traditional leadline surveys would have returned in a full survey season. For example, there have been more than 5.9 billion soundings in the Bay of Fundy since 1994.

The *Matthew* is equipped with a Kongsberg EM710 multibeam echo sounder (MBES) which operates in a band of frequencies from 70 to 95 kHz. Its coverage in typical survey mode is 60° either side of nadir. This equates to a swath width of about 3.5 times water depth. The EM710 can sound to depths of 1,500 m. The launches are similarly equipped with Kongsberg EM3002 sounders, but can only work to depths of 150 m. With the newer versions of software, these sounders can log water column backscatter. Water column backscatter can image schools of fish and aid in mapping the least depth over hazards such as wrecks.

The *Matthew* is also equipped with a ram-mounted, 3.5 kHz sub-bottom profiler—a single-beam echo sounder with the power to sound nearly 30 m into the seabed. This transducer is mounted on a pole that extends vertically below the ship when in survey mode, which reduces interference by the ship's hull. The seabed profile is used with the backscatter obtained from the multibeam data to assess the makeup of the seabed. Ground truthing also takes place. Bottom samples taken at the same location as the survey, using either a bucket grab or core sample, can be related to the backscatter signal. If a similar return is seen elsewhere, it can be assumed to be the same type of bottom. For example, if the backscatter shows a particular

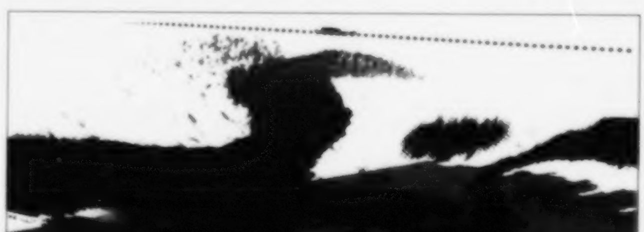


Image shows schools of fish in the water column observed during the survey. Image courtesy of the Ocean Mapping Group, UNB Canada © J.E. Hughes Clarke, OMG/UNB

Low tide at Burncoat Head, Minas Basin – location of the highest tidal range ever recorded on the planet

pattern, and it is known to be a sandy bottom, it can be assumed that if this return is seen elsewhere in the area, then that bottom, too, would be sand.

The *Creed* is a Small Waterplane Area Twin Hull (SWATH) vessel equipped with a Kongsberg EM1002. This sounder is similar to that on the *Matthew* except that it operates at a single frequency of 95 kHz.

VERTICAL DATUM

The four survey platforms were equipped with Omnistar HP GPS receivers which, in addition to providing a position for the ship, provide vertical measurements accurate to within 20 cm. This vertical value allows soundings to be reduced to chart datum in real time. Traditionally, the height of the tide is measured at a single point, and the soundings that are collected in the area are correcte for the tide. Chart datum is a term that refers to the level of wate that the depths shown on the chart are measured from. On Canadiar charts in tidal waters, depths are reduced to low tide, meaning tha a user would always know the minimum depth of water in an are without having to know the state of the tide (barring extrem weather conditions). Collecting tidal data in real time means bein able to record the height of the tide at the same place and time a the soundings. This is important as the tidal signature can var significantly in phase (time) and amplitude (height) between th points of observation of the tide and soundings.

The four survey platforms essentially act as mobile tide gauges These vertical data observations will be used as independent verifi

cation of the existing tide gauge data for the Bay of Fundy. Once validated, the GPS data will be used to improve the tidal model for the Bay of Fundy. During the 2008 survey season, submersible tide gauges and temporary tide gauges were installed to provide additional vertical datum control where possible. Due to the extreme tide ranges of the Bay of Fundy, it is not always possible to install a gauge on a wharf as the length of cable required to prevent the gauge drying out reduces the effectiveness of the gauge.

ODIM-Brooke Ocean MVP-200 Moving Vessel Profiler aboard the CCGS *Matthew*

PROFILES

During operations, the four survey platforms measure sound velocity profiles which correct for refraction. The *Matthew* and the *Creed* have Brooke Ocean Technology (ODIM) Moving Vessel Profilers (MVP-200 and MVP-100, respectively) installed which allow for casts to be taken while underway. (Note page 12, MVP profile winch in blue at stern of each vessel.)

The *Matthew's* multi-sensor free fall "fish" is equipped with a conductivity, temperature, and depth sensor, a sound velocity and pressure sensor, and a fluorometer (measures fluorescence). In addition to the normal casts taken for hydrographic purposes, the *Matthew* occasionally records casts across and along the axis of the Bay during transits. Currently, the UNB Ocean Mapping Group is using this cast data as part of its research. This information can provide valuable insight into the dynamics of the tide cycle.

Although the significant work accomplished over the past three years has resulted in an exceptional amount of data being amassed, the real work starts with the processing and analysis of datasets such as bathymetry, water column, and vertical datum. Some data is already making its way into production such as the new editions of nautical charts in the approaches to Saint John, NB. This overall data set serves both to see the Bay of Fundy as it's never been seen before, and to provide a base against which future impacts to the habitat can be measured.

The Labrador Coast Inshore Route – Finally Complete, After 75 Years

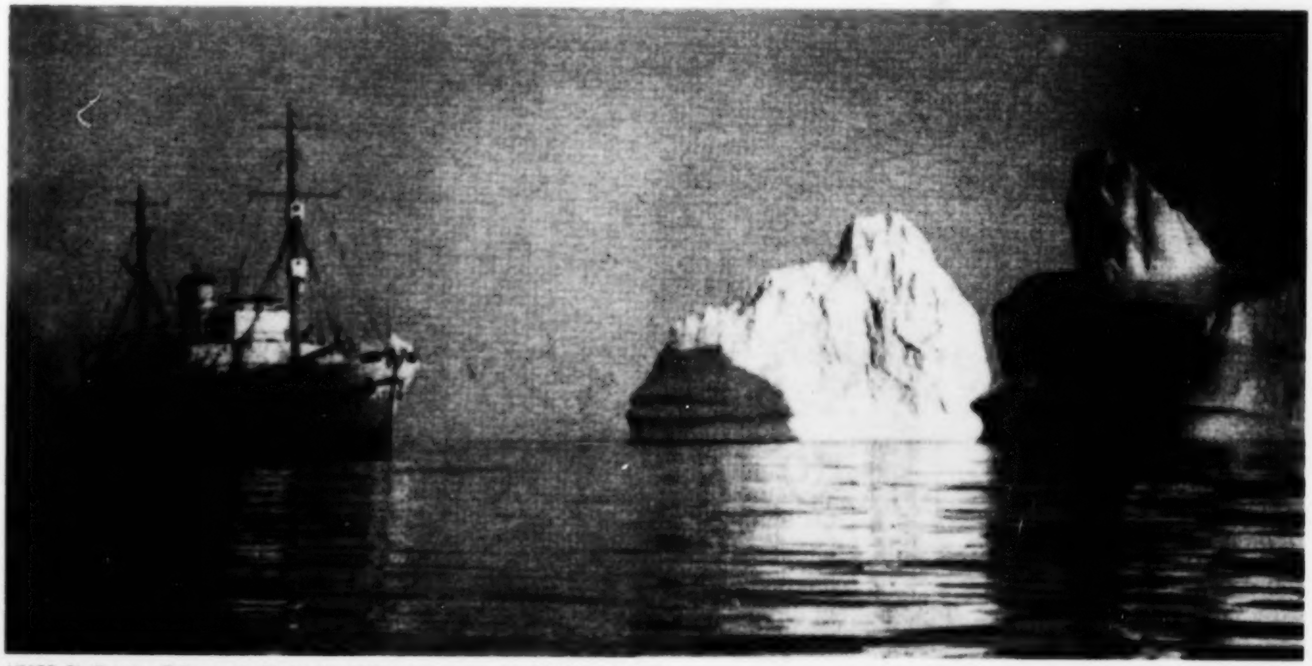
Michael Lamplugh

The Canadian Hydrographic Service (CHS) Atlantic has achieved a significant milestone deserving of celebration. In 2007, 75 years after the first efforts to survey an inshore route along the entire length of the Labrador Coast, that route was completed.

Frontier charting is a resource-intensive commitment. It is not always a straightforward endeavour to carry out such operations, especially when there is competition for resources from established marine hubs such as Halifax, Sydney, and St. John's. The CHS Atlantic has been working diligently for many years to complete this inshore survey—a goal that even precedes Newfoundland's 1949 entry into Canada.

In 1930, the Hydrographer of the Royal Navy (British Admiralty) responded to pressure from the Colonial Office to initiate surveys for an inshore route north of Newfoundland (i.e., the Labrador coast) and tasked the newly constructed survey vessel HMS *Challenger* to perform this survey work. In July 1932, the *Challenger*, with two survey launches aboard, departed St. John's, Newfoundland bound for Nain, Labrador. Survey operations were started in that area and progressed in a southerly direction. Back then, positioning was done by horizontal sextant angles and depths were obtained by hand with lead lines. The ship, however, was fitted with the recently developed British Admiralty Pattern Echo-Sounder, the most modern sounding equipment. This was a very early version of an acoustic sounder, which involved the operator "listening" for the loudest return pulse from the seafloor after a steel plate in the ship's hull was struck by an electronic hammer. However, because of the complexity of the coastline and the lack of foreseeable shipping in this area, surveying lasted only three years. For many years, the *Challenger's* tracks from transiting the coast to Nain were the only data a mariner had north of Cartright, Labrador.

It was predictable that, in time, increased shipping along the Labrador coast due to pressures such as the opening of the Arctic,



HMCS *Challenger* off the coast of Labrador, 1932 - photo courtesy of William Glover

Voisey's Bay nickel development, oil and gas exploration, and eco-tourism would create the need for hydrographic surveys and charts to modern standards. Therefore, over the intervening years, the CHS worked hard to expand the early results. The magnitude and complexity of the coast did not allow for a quick or easy completion. In the late 1970s, the CSS *Maxwell* started working north of Cape Harrison. Then the CSS *Baffin* (with her six launches) put in many years moving the surveyed route north into the more hazardous and unknown waters. By comparison, the waters of southern Labrador had been well known by mariners for hundreds of years. For example, Red Bay (on the Strait of Belle Isle) was used by Basque whalers from France and Spain who came over annually after about 1530, to harvest the abundant right and bowhead whales.

The CHS Atlantic Survey team: (front) Michael Lamplugh, Hydrographer-in-Charge; (back, from left) Isabelle Santarelli (student from France), Andrew Craft, Julie LeClerc, Michael Collins, Chris LeBlanc, Morley Wright, and Christian Solomon

With the arrival of the CSS *Matthew* to the east coast survey fleet in 1990, an ongoing annual survey of the Labrador coast was initiated. However, significant yearly progress did not really start until the advent of GPS positioning as well as multi-beam capability in 1995 aboard the launch *Plover*. By 2004, the inshore route coverage had progressed to Cape Mugford, approximately 180 km past Nain. In 2005, the *Matthew*'s sonar was upgraded to a state-of-the-art multi-beam system; that year the last (360-kilometre) section from Cape Mugford to Cape Chidley was undertaken. The big difference over previous efforts was that rather than incrementally moving north each year, the CHS Atlantic now attempted to do the entire remaining route in one season. However, this stretch turned out to contain the most complex and treacherous areas along the entire coast. In fact, once north of Cape White Handkerchief, the Chief Hydrographer (who has been charting the east coast of Canada for over 30 years) had never before worked in such consistently challenging and dangerous waters. If not for the multi-beam technology

Map shows the extent of the *Matthew's* three-year survey program. The blue areas indicate water depths over 200 metres; the red areas represent under 20 metres. The original goal was a two-mile-wide corridor but extensive shoal areas and very limited choices as to where navigable depths could be found quickly modified this plan.

that enables "looking" port and starboard for shoal depths without endangering the vessel, the survey still would not be complete. Progress was made in 2006 but it was not until 2007, when the *Matthew's* second launch (*Pipit*) was also equipped with a multi-beam sounder, that there was a chance of completing the survey within the four-week window available. With this three-vessel sounding capability, the CHS felt the objective was within reach.

On August 16, 2007 the *Matthew* left Nain and headed north on the first day of a highly unusual and fortuitous 22-day stretch of fair weather which allowed, finally, for the achievement of the objective. In addition to completing the route, the *Matthew* survey flotilla was able to chart McLelan Strait and Grenfell Sound. This approximately 20-km-long narrow passage between the Atlantic Ocean and Ungava Bay had rarely been transited, let alone surveyed. The difference in tidal ranges between these two bodies of water made for a very interesting day's work with very strong currents experienced from the Ungava Bay side shortly after high water. It was not for the faint of heart or for those who wish to have more than a cable's[1] distance to the shoreline!

Two other significant accomplishments during this three-year effort were the charting of three access routes from the offshore to the inshore route and the establishment of a number of harbours-of-refuge. When this information is published, all mariners transiting the Labrador Sea will have options if they need to seek shelter. There are now a number of excellent surveyed anchorages in northern Labrador. Prior to this, they had to stay well offshore due to the uncharted rocks and reefs within 32 kilometres (20 miles) of the coast.

The Canadian Hydrographic Service has started work on extending the chart series on the Labrador coast. There will be 11 new charts

CCGS *Matthew* sounding (slowly) near shore in Hebron Fiord: the launch, *Plover*, is visible in the starboard chocks.

[1] Cable is a nautical term that refers to one-tenth of a nautical mile (which is one minute of latitude, or approximately 185 metres).

Map shows the extent of the *Matthew*'s three-year survey program. The blue areas indicate water depths over 200 metres; the red areas represent under 20 metres. The original goal was a two-mile wide corridor but extensive shoal areas and very limited choices as to where navigable depths could be found quickly modified this plan.

that enables "looking" port and starboard for shoal depths without endangering the vessel, the survey still would not be complete. Progress was made in 2006 but it was not until 2007, when the *Matthew*'s second launch (*Pipit*) was also equipped with a multi-beam sounder, that there was a chance of completing the survey within the four-week window available. With this three-vessel sounding capability, the CHS felt the objective was within reach.

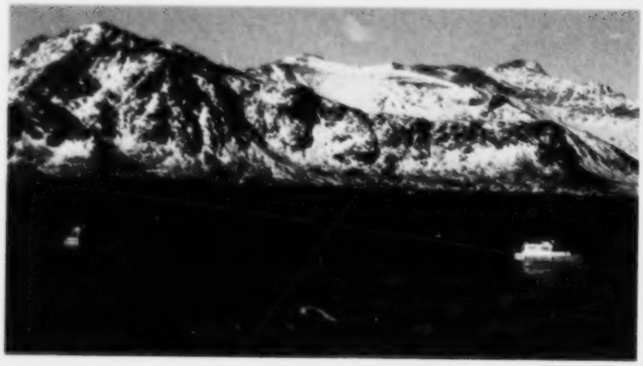
On August 16, 2007 the *Matthew* left Nain and headed north on the first day of a highly unusual and fortuitous 22-day stretch of fair weather which allowed, finally, for the achievement of the objective. In addition to completing the route, the *Matthew* survey flotilla was able to chart McLelan Strait and Grenfell Sound. This approximately 20-km-long narrow passage between the Atlantic Ocean and Ungava Bay had rarely been transited, let alone surveyed. The difference in tidal ranges between these two bodies of water made for a very interesting day's work with very strong currents experienced from the Ungava Bay side shortly after high water. It was not for the faint of heart or for those who wish to have more than a cable's[1] distance to the shoreline!

Two other significant accomplishments during this three-year effort were the charting of three access routes from the offshore to the inshore route and the establishment of a number of harbours of refuge. When this information is published, all mariners transiting the Labrador Sea will have options if they need to seek shelter. There are now a number of excellent surveyed anchorages in northern Labrador. Prior to this, they had to stay well offshore due to the uncharted rocks and reefs within 32 kilometres (20 miles) of the coast.

The Canadian Hydrographic Service has started work on extending the chart series on the Labrador coast. There will be 11 new charts

CCGS *Matthew* sounding (slowly) near shore in Hebron Fiord; the launch, *Plover*, is visible in the starboard chocks.

[1] Cable is a nautical term that refers to one-tenth of a nautical mile (which is one minute of latitude) or approximately 185 metres.



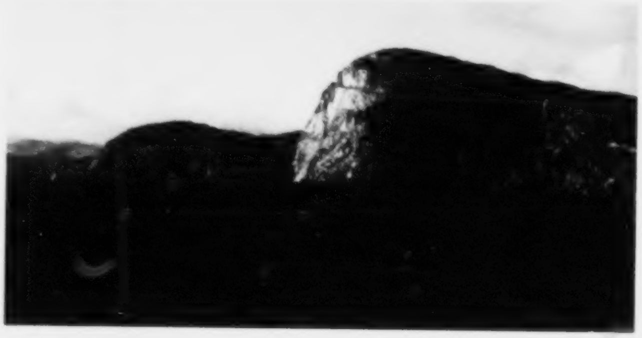
Launches *Plover* (left) and *Pipit* off Trout Trap Fiord at the start of a day's sounding

This spectacular sunrise, while the *Matthew* was anchored in Ryans Bay on September 8, 2007 signaled the end of the incredible stretch of fair weather and the completion of the survey of an inshore route along the Labrador coast, begun 75 years ago.

compiled: three at a scale of 1:100,000, one at 1:200,000, and seven at 1:40,000. This will allow twelve off-datum[2] charts in this area to be cancelled. These new charts, released for the start of the 2009 shipping season, will also allow the truly adventurous to navigate safely to Canada's newest national park, Torngat Mountains National Park.

Upon reflection, there are some interesting links between the *Challenger* and the *Matthew*. Both are dedicated hydrographic survey platforms with two survey launches equipped with the most modern survey instrumentation of their day. One started and the other completed the inshore route; however, they both initiated their efforts from the same place— Nain, the northernmost community in Labrador. Seventy-five years is a long time to complete a survey program, but it is a credit to our forefathers to have seen the need to have this area well charted. They would have been very surprised however, to see what was required and how long it took to complete the task.

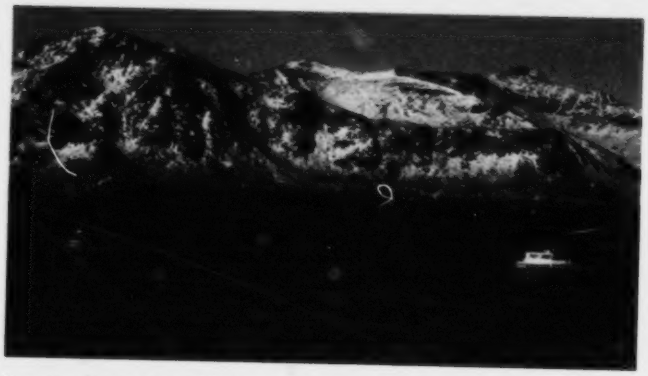
All photographs in this article were taken by Michael Lamplugh.



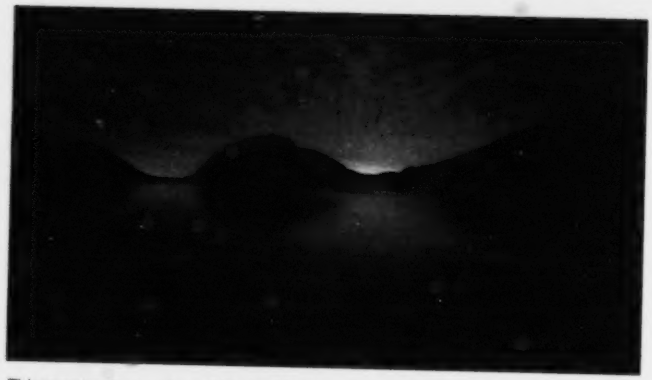
Cape Chidley is the most northern point in Labrador and the Torngat Mountains National Park. Torngat Mountains became Canada's 42nd national park on July 10, 2008, upon settlement of Inuit land claims. Cooperatively managed by Parks Canada, the Makivik Corporation (Inuit of Nunavik, Northern Quebec), and the Nunatsiavut Government (formerly the Labrador Inuit Association), the park is a wonderful example of a collaborative negotiation that could be a model for future discussions. Map courtesy of Parks Canada Agency

Editor's note: McLelan Strait is the correct spelling.

[2] An off-datum nautical chart is one which is usually correct for horizontal distances, so radar positioning will work well, but its exact geographic coordinates are unknown. Therefore, positioning and navigating with GPS is not advisable.



Launches *Plover* (left) and *Pipit* off Trout Trap Fiord at the start of a day's sounding

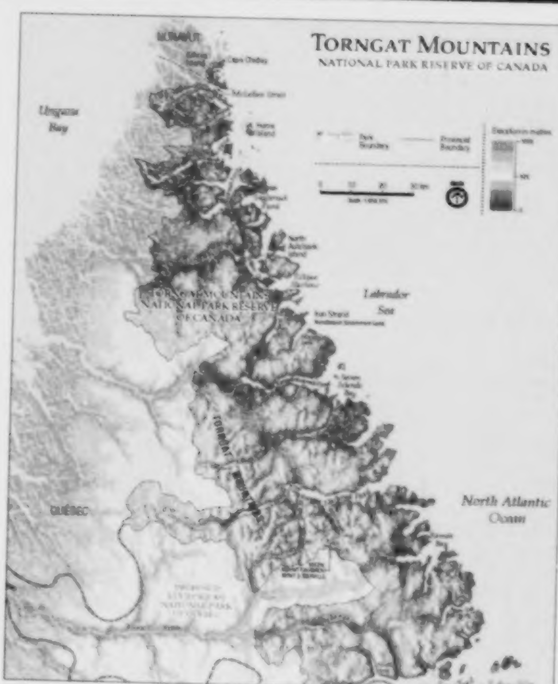


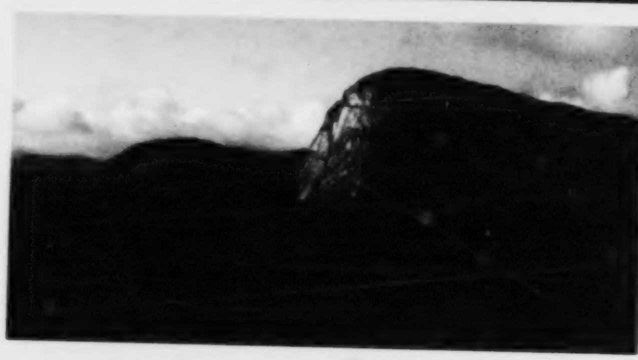
This spectacular sunrise, while the *Matthew* was anchored in Ryans Bay on September 8, 2007 signaled the end of the incredible stretch of fair weather and the completion of the survey of an inshore route along the Labrador coast, begun 75 years ago.

compiled: three at a scale of 1:100,000, one at 1:200,000, and seven at 1:40,000. This will allow twelve off-datum[2] charts in this area to be cancelled. These new charts, released for the start of the 2009 shipping season, will also allow the truly adventurous to navigate safely to Canada's newest national park, Torngat Mountains National Park.

Upon reflection, there are some interesting links between the *Challenger* and the *Matthew*. Both are dedicated hydrographic survey platforms with two survey launches equipped with the most modern survey instrumentation of their day. One started and the other completed the inshore route; however, they both initiated their efforts from the same place— Nain, the northernmost community in Labrador. Seventy-five years is a long time to complete a survey program, but it is a credit to our forefathers to have seen the need to have this area well charted. They would have been very surprised however, to see what was required and how long it took to complete the task.

All photographs in this article were taken by Michael Lamplugh.





Cape Chidley is the most northern point in Labrador and the Torngat Mountains National Park. Torngat Mountains became Canada's 42nd national park on July 10, 2008, upon settlement of Inuit land claims. Cooperatively managed by Parks Canada, the Makivik Corporation (Inuit of Nunavik, Northern Quebec), and the Nunatsiavut Government (formerly the Labrador Inuit Association), the park is a wonderful example of a collaborative negotiation that could be a model for future discussions. Map courtesy of Parks Canada Agency

Editor's note: McLelan Strait is the correct spelling.

[2] An off-datum nautical chart is one which is usually correct for horizontal distances, so radar positioning will work well, but its exact geographic coordinates are unknown. Therefore, positioning and navigating with GPS is not advisable.

The Search for HMSC *Shawinigan*

Lieutenant(Navy) Jason Karle

HMCS *Shawinigan*

Today, many may not remember or be aware of the military significance of Halifax Harbour in the years spanning 1939-1945, when thousands of ships were organized into large convoys carrying essential supplies from food to medicine and young men and women destined to take on a role in the war effort. In addition to the inherent risk of crossing the North Atlantic, these resources were susceptible to surprise attacks from German U-Boats—a significant cause of naval shipping losses. Over 500,000 tonnes were lost in June, 1941 alone. To combat the underwater threat and provide some protection to these vulnerable units, the Royal Canadian Navy tasked the Flower Class Corvettes to act as escort. Corvettes were minimally armed and well known for their lively ride in rough seas and weather. However, they were exceptionally robust and seaworthy and well loved for the protection they brought to the convoys. During the war, the Corvettes escorted 250,000 merchant ships (multiple voyages) and directly sank, or led to the sinking of, 15 U-Boats.

One of these remarkable ships, HMCS *Shawinigan*, was launched May 1941 and served in the Royal Canadian Navy as an escort unit for Atlantic convoys and local shipping. During one of her routine tasks escorting the ferry between Porte Aux Basques, Newfoundland to Sydney, Nova Scotia on the proverbial dark and stormy night, the *Shawinigan* went missing with all hands lost. Due to uncertainty about why the *Shawinigan* went missing and no eyewitness accounts, the search area was enormous. The largest search-and-rescue operation (of the time) was mounted in an effort to locate any survivors and the wreckage. No survivors, only two bodies, and a few pieces of wreckage were ever found, many miles from the corvette's expected location. The site, and initially the cause, of the disappearance remained a mystery. It was not until several months later, as the war drew to a close, that a young U-Boat (U1228) captain was interrogated and claimed that he had sunk the *Shawinigan* with torpedoes near Port Aux Basques on the date of her disappearance. This was the first in a series of clues in the search for the corvette.

With the upcoming 100th anniversary of the Canadian Navy, a previously shelved initiative to locate the HMCS *Shawinigan* was given new life. Although an earlier survey had been attempted using an older side-scan sonar system in combination with a magnetic anomaly detector, little progress had been made, because of system limitations. The renewed plan was to conduct a multi-beam bathymetric survey, while towing a magnetometer, within the area most likely to contain the wreck (based on historical interviews and meteorological data), to provide a detailed profile of the seabed and generate areas of highest probability to narrow the search area. In September 2008, five members from the TRINITY Route Survey Office spent almost a week onboard the CCGS *Matthew* to advance the search for the *Shawinigan*. Over 30% of the search area (152 square nautical miles) was covered in the brief weather window available. Although it is disappointing that the entire area could not be covered, valuable data that will be added to the CHS database was collected. The survey also allowed Navy personnel to gain valuable multibeam experience.

Armed with the data and the lessons learned, a second survey is planned for spring 2009 to complete the multi-beam data collection, which will be correlated with the magnetometer data. The search area will be refined to include only the areas that meet the criteria of shape, size, magnetic signature, and location. This will then allow the Navy to conduct a high-resolution side-scan sonar survey on the targets of interest, and with luck and a great deal of patience, locate the final resting place of the HMCS *Shawinigan*.

The search for the *Shawinigan* has been an interesting

endeavour. For Navy personnel it was a different experience to look for a ship instead of small sea-bottom objects. Also, trying to locate the final resting place of fellow brothers-in-arms instilled a sense of pride. As time permits, the search for the *Shawinigan* will continue until she is located and we are able to pay respect to those who gave the ultimate sacrifice.

Impacts of Severe Arctic Storms and Climate Change on Arctic Coastal Oceanographic Processes

[1]Will Perrie, [2]Eyad Atallah, [2]Melanie Cooke, [3]Ewa Dunlap, [2]John Gyakum, [4]Azharul Hoque, [1]Zhenxia Long, [1]Ryan Mulligan, [2]David Small, [4]Steve Solomon, [1]Charles Tang, [1]Bechara Toulany, and [1,5]Lujun Zhang

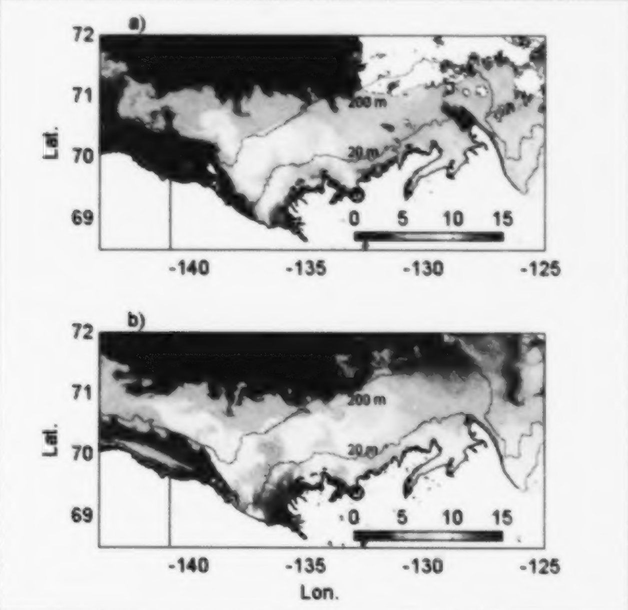
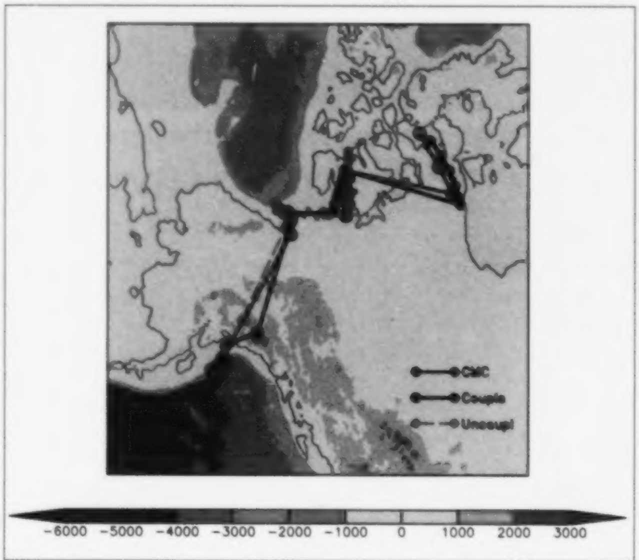
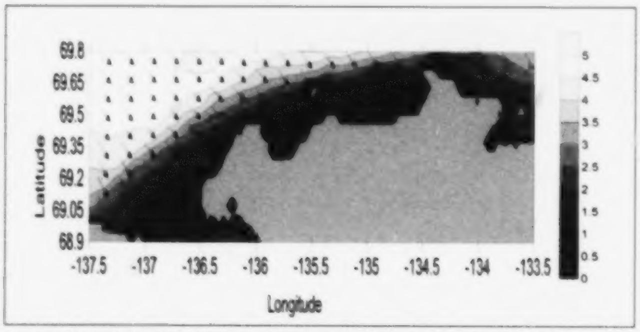


Figure 1. Sea surface temperatures from MODIS satellite observations on August 23 and 25, 2007 show the extent of the Mackenzie River plume in the Beaufort Sea. Easterly winds cause upwelling, stronger mixing, and a cooler plume (upper panel); light winds with minimal mixing and entrainment of underlying shelf water allow the warmer plume to spread as a thin surface layer (lower panel). The coastline and 20-m and 200-m bathymetric contours are shown. Instabilities are visible near the shelf break (200-m contour) where the Coriolis-dominated eastward flow on the shelf meets the westward-flowing Beaufort Gyre in Canada Basin. Tuktoyaktuk is indicated by 0.

BIO scientists in DFO's Ocean Sciences Division and in NRCan are involved in an International Polar Year (IPY) project, *Impact of Severe Arctic Storms and Climate Change on Coastal Oceanographic Processes*, whose focus is to simulate and understand coastal oceanographic processes driven by intense storms and severe weather in the southern Beaufort Sea and related waters of the western Canadian Arctic. This area is important because the communities and industrial infrastructure are concentrated at the coast and are being impacted by coastal erosion and sediment transport processes related to marine storms. The area is also undergoing hydrocarbon exploration with potential development of the nearshore within the next decade. The project is doing detailed studies of coastal oceanographic processes, including sea ice and ocean currents, waves, storm surges, marine winds, and related nearshore coastal erosion and sediment transport effects. Important factors are the changing extent of open water and ice, as well as the associated oceanic surface fluxes which modify Arctic storm development, including storm tracks and marine winds, and storm-generated waves and





Figures 2a and b. Storm track simulations are shown of a rapidly developing storm that caused coastal damage along the southern coast of the Beaufort Sea in September 1999. Shown are (a) the control storm tracks simulation (Uncoupled), the coupled (Coupled) simulation, and the CMC analysis storm track; and (b) corresponding wave heights in metres (legend on right) and mean wave directions during the peak of the storm.

currents. Changes and natural variability in weather and climate, including in storm tracks and intensities, associated with warming in the Beaufort-Chukchi region, can endanger coastal settlements, their expected use of coastal marine environments, aquatic species, and activities related to offshore resource development. The important time scales to investigate possible climate change and variations range from a few days for selected storms, to seasonal, interannual, decadal, and longer.

Basic numerical simulations and data studies have been completed and historical storm and climate/reanalysis data, recent observational data, and analysis software have been assembled. Models for coupled simulations of ocean waves, sea ice, ocean circulation, atmospheric storm events, and regional climate have been implemented, tested, and improved using observations collected from recent storms and climate reanalysis data sets. The ocean model was coupled to a multi-category sea-ice model with a model domain covering the entire Arctic Ocean. An important contribution to the project was a recent 20-year climate study for Beaufort Sea wind and waves by the Canadian Meteorological Centre (CMC).

Detailed studies aimed at understanding the interactions between the MacKenzie Delta area and the Beaufort Sea during storm conditions related to storm surges and coastal flooding events have been completed. Figure 1 shows the sea surface temperature (SST) in late August in 2007 from MODIS (Moderate Resolution Imaging Spectroradiometer) satellite observations. Some of the detailed interactions among the warm river water, the coastal water, and the Beaufort gyre (farther offshore) are evident in response to wind-related forcing. In-situ measurements of temperature and salinity also were collected at about 25 km north from the Delta coastline. Based on these data and fine-resolution computer simulations, the salinity patterns were estimated to be similar to the spatial temperature variations in Figure 1.

Further investigations are needed to clarify the causes of vegetation die-offs during storm surges in coastal areas, which can reach as far as 25 km inland from the coast. Such a storm surge was generated by a storm in September 1999. This storm is shown in model simulations and comparisons with CMC data (Figure 2). The storm initially developed as a cyclone over the Northeast Pacific, intensified explosively in the Gulf of Alaska, and made landfall at Cape Newenham on September 23. It rapidly moved north-northeastward, crossed the Rockies to the Yukon and Northwest Territories, and re-intensified over the southern Beaufort Sea, over a zone of high sea-surface temperature gradients on September 24. It lingered in the Beaufort Sea, causing extensive coastal damage to communities, before moving into the Arctic Archipelago and dissipating by September 27. The ocean surface had little impact on storm development, as shown by the comparisons of coupled and uncoupled atmosphere-ice-ocean model simulations in Figure 2a, because much of the storm track is over land, and although the storm did spend a couple of days over the Beaufort Sea, this occurred during the decay phase of the storm's life cycle and had little effect on its remaining development.

In terms of climatology, the strongest surface winds along the southern Beaufort coast are either from the northwest or from the southeast, occurring in the fall and winter seasons. Future work will focus on a more detailed analysis of the life cycle of the planetary-scale atmospheric circulation regimes impacted by these strong wind

Figures 3a and 3b. Photographs show, at the base of the bluff, an example of morphodynamic change in a thermo-erosional notch composed of frozen fine sand and silt with scattered cobbles and boulders: (a) development of the niche and (b) later block failure of the same cliff.

events, and analysis of trends during the past 60 years. In preliminary analyses, we found that storms responsible for significant surge events are associated with a series of unusually strong upper-atmosphere forcing events spanning the hemisphere along 70° N. Ongoing investigations involve identifying whether these storms represent a unique, but not climatologically prevalent flow regime, or whether they are transitions in flow regimes such as the North Atlantic Oscillation or Pacific North American Pattern. Moreover, we found that such events occur more often in the late summer and early autumn months. A precursor, common to each of the extreme storm surge cases, is cold air damming north of Brooks Range that produces

strong northwesterly winds favourable for storm surges. Additional meteorological phenomena, of varying spatial and time scales and of varying predictabilities, which may play significant roles in the strong northwesterly winds responsible for these extreme events, are being documented.

Preliminary studies of coastal erosion, sediment transport, and morphodynamic changes in nearshore areas along the Beaufort coastline are complete. Under storm conditions, the water levels rise to allow the waves to break against the frozen cliff face and gradually remove the material by a combination of melting and hydrodynamics (thermal and mechanical erosion). The September 1999 storm is an example of this action. At the peak of the storm, dominant waves were oriented from the northwest, as shown in Figure 2b, and had their strongest impact on the fragile coast of the MacKenzie Delta.

The north-facing side of Tuktoyaktuk Island sits at the entrance to Tuktoyaktuk Harbour and provides natural protection from waves (Figures 3a and 3b). Over time, niches are formed, (e.g., by the September 1999 storm) which can reach 10 m deep into the bluff and can be 2 m high. Once the niche cuts sufficiently into the base of the cliff, the cornice that overhangs the niche collapses, causing block failure. The frozen bluffs are also cut by "patterned ground" which forms polygonal structures defined by ice wedges. When the blocks fail, they tend to do so along the lines of weakness defined by the ice wedges. The failure can occur days, weeks, or months following the development of the niches. During the last several years, erosion measurements by air photos have shown that the north side of Tuktoyaktuk Island is eroding at a long-term average rate of about 2 m per year (up to 7 m during a single storm event). At the present long-term erosion rate, by 2050, the island will be reduced to little more than a shoal for much of its length, allowing large waves to enter the harbour. Tuktoyaktuk Harbour is the only developed harbour for hundreds of kilometres.

The project ends in March 2011. By that time, further studies will have been completed and models tested, validated, and improved using IPY field data. Tests will focus on selected storms, as well as seasonal, inter-annual, and decadal time scales. The project will attempt to establish links among climate change, the diminishing ice coverage, and coastal ocean processes, for erosion and sediment transport. Adaptation strategies relevant to coastal communities will be recommended.

DFO's Ocean Sciences Division is included also in three IPY-approved network projects: (1) iAOOS (the Integrated Arctic Ocean Observing System), (2) THORPEX (Improved numerical weather forecasting and climate simulations by exploitation of in-situ, airborne remote-sensing and satellite data, advanced modelling systems, and basic research into polar processes and into polar-global interactions), and (3) ACCO-net (the Arctic Circum-Polar Coastal Observatory Network). Important support is also given by IPY field projects and other programs, e.g., the Federal Panel on Energy Research and Development, which actively collect data on wind, waves, currents, and related coastal ocean and marine boundary layer variables.

[1]DFO, BIO, Dartmouth, Nova Scotia, Canada
[2]Department of Atmospheric and Oceanic Sciences, McGill University, Montreal, Quebec, Canada
[3]Department of Oceanography, Dalhousie University, Halifax, Nova Scotia
[4]NRCan, BIO, Dartmouth, Nova Scotia
[5]Department of Atmospheric Sciences, Nanjing University, Nanjing, China

Breaking Hard Ice: Development of a Seismic System to Define the Extended Continental Shelf and Garner Geological Secrets from Canada Basin beneath the Arctic Icepack

*John Shimeld, Ruth Jackson, Borden Chapman, Jacob Verhoef, and Thomas Funck**

As has been widely reported in the media, the areal extents of the Arctic Ocean icepack during the summers of 2007 and 2008 were the lowest and second lowest, respectively, ever recorded since reliable satellite observations began in 1979. Nonetheless, with an area exceeding 2.5 million square km even at the height of summer, the vast frozen expanse of the Arctic icepack is significantly larger than Greenland. Indeed, in both regions, ice conceals very effectively what lies below and poses daunting challenges for scientific researchers.

Prevailing winds drive the Arctic icepack against the northern margin of Canada from Ellesmere Island to Banks Island. Large floes are often trapped here for several years and, easily able to withstand the summer melt, they thicken to 3.5 m or more. Strong shifting winds jostle the icy behemoths against each other, forming long contractional ridges that can exceed 15 m in total thickness. Such conditions hinder and sometimes completely repel attempts to collect scientific data using even the most powerful icebreakers in the world—in 2007, for example, the Russian nuclear icebreaker, *50 Let Pobedy*, with approximately 75,000 horsepower, was unable to penetrate the difficult ice conditions north of Ellesmere Island. It can be easily understood, then, why so little is known about this part of the planet and, in particular, why fundamental questions remain about its geological evolution.

New motivation and significant funding for geological study of the Arctic Basin is being driven by a fascinating marriage of international politics and science under the United Nations Convention on the Law of the Sea. Article 76 of the convention provides a means for member states to define a juridical boundary, known as the Extended Continental Shelf (ECS), beyond the 200 nautical mile limit of the Exclusive Economic Zone. Within the ECS zone,

Figure 1. Map of Canada Basin – seismic reflection profiles collected during 2007 and 2008 are indicated with black and green lines, respectively.

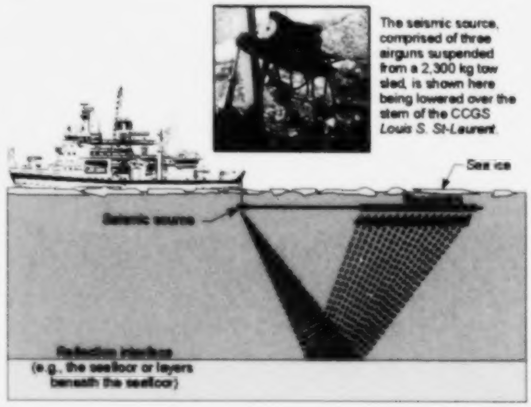


Figure 2. Schematic diagram of the system used to reliably collect seismic reflection data using icebreakers under a range of light-to-heavy ice conditions

member states can exercise sovereign rights to explore, exploit, conserve, and manage both non-living and living resources that lie on and beneath the seabed. Resources could include conventional oil and gas, ferromanganese crusts and nodules, gas hydrate deposits, deep-sea corals, clams, crabs, scallops, sponges, and mollusks.

Under Article 76, member states can define the ECS using geophysical data to determine water depth, thickness of sedimentary rocks, and the nature of the underlying geology along the continental margin. A wide variety of geophysical datasets can be employed including single- and multibeam echosoundings[1] (the primary datasets necessary for work under Article 76), seismic reflection and refraction profiles[2], and measurements of the Earth's gravitational and magnetic fields[3]. Such datasets are important for definition of the ECS, and therefore sovereign rights, but they are also invaluable for science.

Along the western Arctic margin of Canada, geologists have long inferred that ancestral river systems of the Beaufort-Mackenzie and Arctic Archipelago basins transported large volumes of sediment northwards to the deep ocean basin. In the context of Article 76, to demonstrate the presence of these sedimentary sequences and to determine their thickness, seismic data are essential across a region of Canada Basin extending 350 nautical miles from Canadian shores over water depths exceeding 2,500 m (Figure 1). Since seismic datasets were virtually absent in this region, technical staff, researchers, and managers with the Geological Survey of Canada began, in 2005, to work closely with members of the Canadian Coast Guard to develop a seismic system that could be used reliably on icebreakers under potentially heavy ice conditions.

The feasibility of this concept was tested during a 2006 cruise on the CCGS *Louis S. St-Laurent* using many ideas from the international community of researchers who collect similar data, but in other regions of the Arctic where ice conditions are generally less harsh. In comparison with conventional marine seismic reflection systems that are designed to provide optimal results in open water, a system for use in polar icepacks must compromise some aspects of data quality in order to achieve reliable results and avoid damage from the ice. The system designed by technical staff at the GSC uses a seismic source mounted on a 2,300 kg sled (Figure 2). It is towed immediately astern of the icebreaker and below the propellers to avoid being lifted by their powerful wash. Seismic energy is generated by the source, which

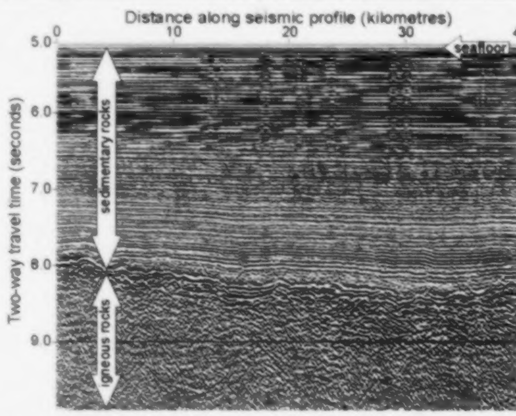


Figure 3. Example profile of the high quality seismic reflection data collected during the 2008 joint program with the CCGS *Louis S. St-Laurent* and the USCGC *Healy*

[1] Echosounding is a technique in which pulses of energy, vibrating thousands of times per second, are directed through the water from a research vessel such as a ship, submarine, or underwater autonomous vehicle. Energy that is reflected off the seafloor back to the vessel is recorded. When combined with measurements of the speed of sound in water, the echosoundings can be accurately converted to water depths. Single-beam echosoundings provide a two-dimensional graph of water depth beneath the vessel, whereas multibeam echosoundings provide three-dimensional map views of the seafloor.

[2] Seismic profiling is similar to echosounding except that seismic energy pulses vibrate only tens to hundreds of times per second and, as a result, are capable of penetrating several kilometres or more beneath the seafloor. Reflected energy is recorded and plotted on a seismic reflection profile, and this gives a two-dimensional image of layers within the Earth. The speed at which seismic energy travels through the Earth can be determined by recording and analyzing energy that has been refracted (or bent) by the various layers. This information, which is called a seismic refraction profile, is then used to calculate the depth to each layer.

[3] Minute spatial changes in the gravitational and magnetic fields of the Earth can be measured accurately. Such changes manifest variations in density and magnetization linked to different rock types and fundamental variations in the Earth's crust.

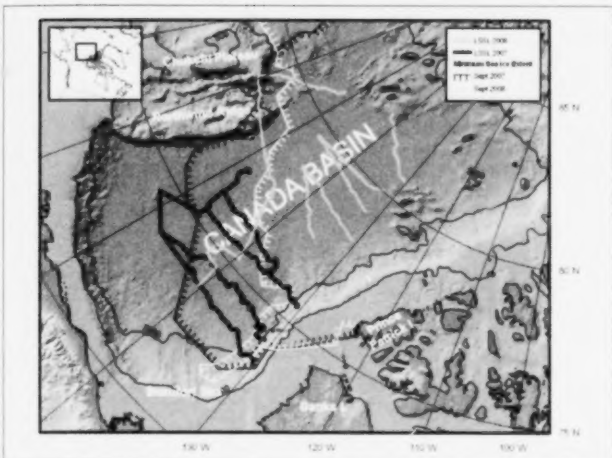


Figure 1. Map of Canada Basin – seismic reflection profiles collected during 2007 and 2008 are indicated with black and green lines, respectively.

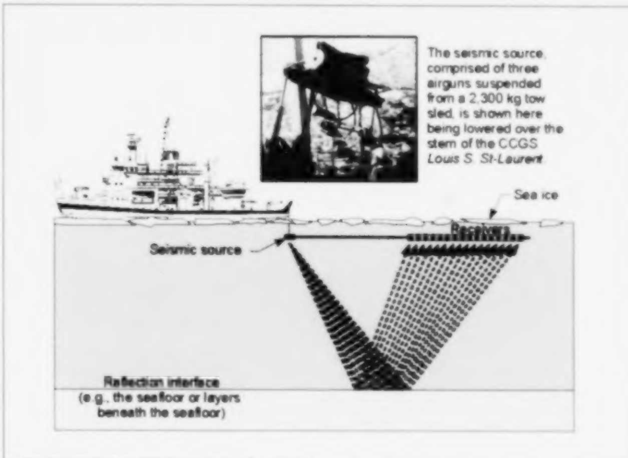


Figure 2. Schematic diagram of the system used to reliably collect seismic reflection data using icebreakers under a range of light-to-heavy ice conditions

member states can exercise sovereign rights to explore, exploit, conserve, and manage both non-living and living resources that lie on and beneath the seabed. Resources could include conventional oil and gas, ferromanganese crusts and nodules, gas hydrate deposits, deep-sea corals, clams, crabs, scallops, sponges, and mollusks.

Under Article 76, member states can define the ECS using geophysical data to determine water depth, thickness of sedimentary rocks, and the nature of the underlying geology along the continental margin. A wide variety of geophysical datasets can be employed including single- and multibeam echosoundings[1] (the primary datasets necessary for work under Article 76), seismic reflection and refraction profiles[2], and measurements of the Earth's gravitational and magnetic fields[3]. Such datasets are important for definition of the ECS, and therefore sovereign rights, but they are also invaluable for science.

Along the western Arctic margin of Canada, geologists have long inferred that ancestral river systems of the Beaufort-Mackenzie and Arctic Archipelago basins transported large volumes of sediment northwards to the deep ocean basin. In the context of Article 76, to demonstrate the presence of these sedimentary sequences and to determine their thickness, seismic data are essential across a region of Canada Basin extending 350 nautical miles from Canadian shores over water depths exceeding 2,500 m (Figure 1). Since seismic datasets were virtually absent in this region, technical staff, researchers, and managers with the Geological Survey of Canada began, in 2005, to work closely with members of the Canadian Coast Guard to develop a seismic system that could be used reliably on icebreakers under potentially heavy ice conditions.

The feasibility of this concept was tested during a 2006 cruise on the CCGS *Louis S. St-Laurent* using many ideas from the international community of researchers who collect similar data, but in other regions of the Arctic where ice conditions are generally less harsh. In comparison with conventional marine seismic reflection systems that are designed to provide optimal results in open water, a system for use in polar icepacks must compromise some aspects of data quality in order to achieve reliable results and avoid damage from the ice. The system designed by technical staff at the GSC uses a seismic source mounted on a 2,300 kg sled (Figure 2). It is towed immediately astern of the icebreaker and below the propellers to avoid being lifted by their powerful wash. Seismic energy is generated by the source, which

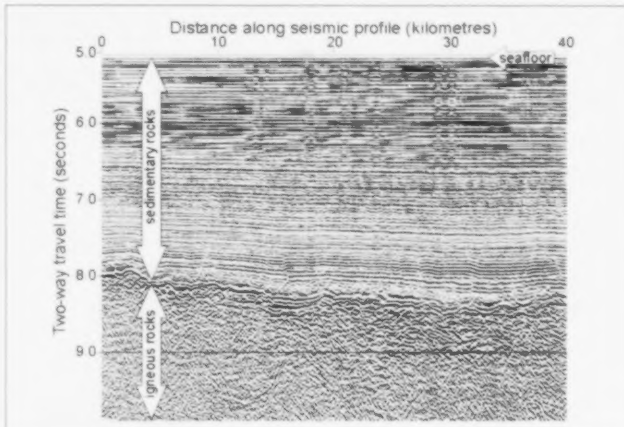


Figure 3. Example profile of the high quality seismic reflection data collected during the 2008 joint program with the CCGS *Louis S. St-Laurent* and the USCGC *Healy*

[1] Echosounding is a technique in which pulses of energy, vibrating thousands of times per second, are directed through the water from a research vessel such as a ship, submarine, or underwater autonomous vehicle. Energy that is reflected off the seafloor back to the vessel is recorded. When combined with measurements of the speed of sound in water, the echosoundings can be accurately converted to water depths. Single beam echosoundings provide a two-dimensional graph of water depth beneath the vessel, whereas multibeam echosoundings provide three-dimensional map views of the seafloor.

[2] Seismic profiling is similar to echosounding except that seismic energy pulses vibrate only tens to hundreds of times per second and, as a result, are capable of penetrating several kilometres or more beneath the seafloor. Reflected energy is recorded and plotted on a seismic reflection profile, and this gives a two-dimensional image of layers within the Earth. The speed at which seismic energy travels through the Earth can be determined by recording and analyzing energy that has been refracted (or bent) by the various layers. This information, which is called a seismic refraction profile, is then used to calculate the depth to each layer.

[3] Minute spatial changes in the gravitational and magnetic fields of the Earth can be measured accurately. Such changes manifest variations in density and magnetization linked to different rock types and fundamental variations in the Earth's crust.

Figure 4. The CCGS *Louis S. St-Laurent* and the USCGC *Healy* rafted together in the Arctic icepack after a successful joint program.

releases bubbles of compressed air into the water at 10- to 20-second intervals that are timed to microsecond accuracy. Receivers are wired along the length of a 100-m cable towed behind the source sled at a depth of about 12 m beneath the sea ice. The receivers measure seismic energy that has propagated downward from the source and has reflected back to the surface from layers within the Earth. The measured signals are digitized by electronics in the cable and are then transmitted to a recording system aboard the ship.

As expected, the icebreaking operations during the 2006 test cruise generated noise that significantly degraded the quality of the recorded seismic data. Nonetheless, the test successfully demonstrated the feasibility of the seismic system and revealed the necessity of various design improvements and equipment upgrades. Sometimes complicated protocols had to be developed for ship operations while towing seismic equipment in the icepack, and for marine mammal observation conducted by Inuit wildlife experts. Data processing techniques were also evaluated to enhance geologically meaningful signals while suppressing various forms of noise. The 2006 cruise also continued an ongoing strong technical collaboration with the Geological Survey of Denmark and Greenland which, in preparation for a 2007 seismic cruise north of Greenland, sent a geophysicist to help perform the tests.

With much eagerness, and perhaps some trepidation, the newly upgraded seismic system was used in a production mode for the first time during six weeks in the summer of 2007 aboard the CCGS *Louis S. St-Laurent*. The results surpassed all expectations: 2,967 km of data were collected offshore of Banks Island (Figure 1) under a range of ice conditions, including pack ice up to about 2.5 m in thickness. The quality of the processed data compares favourably with, or, in some cases, exceeds that of other datasets that the Geological Survey of Canada has collected elsewhere in ice-free waters.

Notwithstanding the success of the 2007 program, ice conditions are generally harsher farther to the northeast, offshore of Prince Patrick and Borden islands. So, in 2008, a joint six-week program with the United States Geological Survey was undertaken using the CCGS *Louis S. St-Laurent* to collect seismic data while the USCGC *Healy* broke ice in front. At times when the ice conditions were too heavy to attempt seismic acquisition, the CCGS *Louis S. St-Laurent* led the way so that the multibeam echosounder aboard the USCGC *Healy* could obtain detailed images of the seafloor. Occasionally, ice conditions were so harsh that both ships had to work in tandem. This time 2,817 km of seismic data were collected under conditions that were generally harsher than the previous year, with ice thicknesses reaching about 3 m. The quality of the data is impressive (Figure 3), which manifests the efforts of many people, including ships' officers and crew, over several years. At the end of such a successful program, it was truly a special event when the two icebreakers rafted together and personnel from both ships celebrated with a special barbeque dinner (Figure 4).

The development of a system to collect seismic reflection data in polar icepack regions using icebreakers is but a recent example of the long tradition of collaboration among researchers in different countries to explore the frontiers of science. The United Nations Convention on the Law of the Sea is a noteworthy human achievement that codifies mutual benefits between the international political and scientific realms.

* of the Geological Survey of Denmark

(NRCan Contribution Number 20080722)

Reducing the Risks from Offshore Oil and Gas Exploration: Safe and Sustainable Development Offshore Labrador

Gary V. Sonnichsen and Sonya A. Dehler

The search for new sources of energy is pushing exploration into remote, under-explored sedimentary basins with extreme geological and environmental conditions. Exploration costs and technological risks have risen dramatically with this push into Canada's offshore frontiers. Petroleum deposits, predominantly of natural gas, exist beneath Labrador's continental shelf, and after three decades, energy companies are exploring again, hoping to find sufficient reserves to justify their high production and transportation costs. Deeper water and under-explored basins will be targeted for future exploration and there is a need for new geological models to understand the petroleum potential in these new and challenging locations. Severe conditions related to weather, oceanography, and seabed geology also will make the Labrador petroleum resources extremely challenging to extract. Unless the deposits can be produced safely and cost-effectively, they will remain untouched. The GSC Atlantic of NRCan is targeting its Labrador research to improve exploration drilling success and to reduce the associated environmental risks of hydrocarbon development. GSC Atlantic is providing geoscience knowledge and advice to regulators to ensure that geological risks and hazards are understood and accounted for prior to designing or approving offshore development projects.

STUDYING BASIN GEOLOGY

Exploration of the Labrador margin during the 1970s led to the discovery of five significant finds of natural gas, totaling 4.2 trillion cubic feet. In recent years, renewed exploration interest has led to yearly acquisition of seismic data and multi-year work commitments exceeding $186 million. Gaps in the geological understanding of the tectonic and sedimentation history of the margin are key challenges faced by exploration companies and Canadian energy policy agencies trying to understand Labrador's offshore resource potential.

The Labrador margin (Figure 1) developed during the opening of the Labrador Sea, when thick sedimentary sequences accumulated in a sedimentary basin that formed above the thinned and subsiding edge of the continent. Basin sediments contained organic matter that over time would be transformed to oil and gas. Assessments of the petroleum system and resource potential require determination of the nature of the organic matter (source rock), and identification of the subsurface reservoir to which it migrated. The rifting and burial/uplift history of the margin also plays a role in determining whether or not organic matter was successfully transformed to an oil or gas stage, and effectively trapped in a suitable reservoir.

Recent work by GSC Atlantic researchers has addressed the depositional history of the margin, combining numerical modeling and laboratory studies with interpretations of seismic data that provide pseudo depth images of sedimentary strata within the basin. The reanalysis of microscopic fossils from previous exploration wells is determining the age and geographic setting of the various sedi-

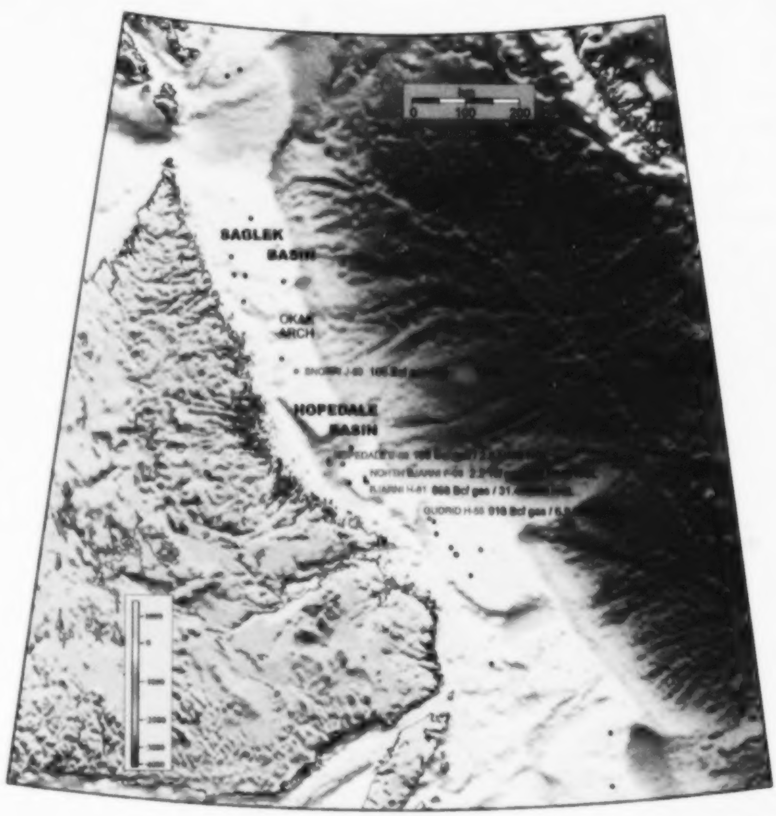


Figure 1. Major gas and natural gas liquid discoveries offshore Labrador, superimposed on regional bathymetry

Reducing the Risks from Offshore Oil and Gas Exploration: Safe and Sustainable Development Offshore Labrador

Gary V. Sonnichsen and Sonya A. Dehler

The search for new sources of energy is pushing exploration into remote, under-explored sedimentary basins with extreme geological and environmental conditions. Exploration costs and technological risks have risen dramatically with this push into Canada's offshore frontiers. Petroleum deposits, predominantly of natural gas, exist beneath Labrador's continental shelf, and after three decades, energy companies are exploring again, hoping to find sufficient reserves to justify their high production and transportation costs. Deeper water and under-explored basins will be targeted for future exploration and there is a need for new geological models to understand the petroleum potential in these new and challenging locations. Severe conditions related to weather, oceanography, and seabed geology also will make the Labrador petroleum resources extremely challenging to extract. Unless the deposits can be produced safely and cost-effectively, they will remain untouched. The GSC Atlantic of NRCan is targeting its Labrador research to improve exploration drilling success and to reduce the associated environmental risks of hydrocarbon development. GSC Atlantic is providing geoscience knowledge and advice to regulators to ensure that geological risks and hazards are understood and accounted for prior to designing or approving offshore development projects.

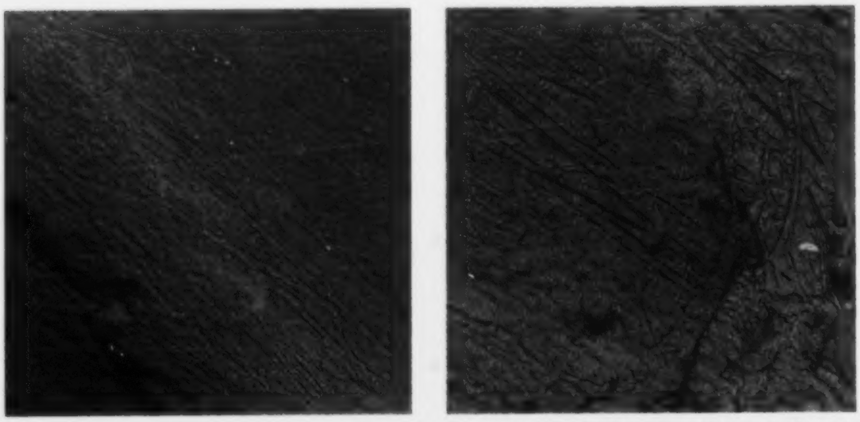
STUDYING BASIN GEOLOGY

Exploration of the Labrador margin during the 1970s led to the discovery of five significant finds of natural gas, totaling 4.2 trillion cubic feet. In recent years, renewed exploration interest has led to yearly acquisition of seismic data and multi-year work commitments exceeding $186 million. Gaps in the geological understanding of the tectonic and sedimentation history of the margin are key challenges faced by exploration companies and Canadian energy policy agencies trying to understand Labrador's offshore resource potential.

The Labrador margin (Figure 1) developed during the opening of the Labrador Sea, when thick sedimentary sequences accumulated in a sedimentary basin that formed above the thinned and subsiding edge of the continent. Basin sediments contained organic matter that over time would be transformed to oil and gas. Assessments of the petroleum system and resource potential require determination of the nature of the organic matter (source rock), and identification of the subsurface reservoir to which it migrated. The rifting and burial/uplift history of the margin also plays a role in determining whether or not organic matter was successfully transformed to an oil or gas stage, and effectively trapped in a suitable reservoir.

Recent work by GSC Atlantic researchers has addressed the depositional history of the margin, combining numerical modeling and laboratory studies with interpretations of seismic data that provide pseudo-depth images of sedimentary strata within the basin. The reanalysis of microscopic fossils from previous exploration wells is determining the age and geographic setting of the various sedi-

Figure 1. Major gas and natural gas liquid discoveries offshore Labrador, superimposed on regional bathymetry.



Figures 2a and 2b. Comparison of scour severity southwest of the Bjarni field (left) and on the inner shelf (right)

mentary units. Chemical analysis of organic compounds from the well cuttings is helping to identify the nature of petroleum source rocks, including at least one oil source. Together, the results of this multidisciplinary study will provide a much stronger geologic framework to support the renewed stage of exploration on this margin.

STUDYING SEABED STABILITY

The stability of the seabed has important economic, environmental, and safety consequences for the placement of drill rigs, wells, and pipelines on the seafloor. With a single offshore well costing at least \$100M and actual development projects costing billions, it is critical that facilities are designed safely with a full understanding of the seafloor geology and the geological processes that may affect seabed stability. The key issue currently being addressed by GSC Atlantic offshore Labrador is the frequency and severity of seabed damage by keel-dragging icebergs.

Some icebergs are so large their keels (the bottom of the iceberg) can scour the seabed in water depths in excess of 200 m. Iceberg furrows can be kilometres long and iceberg pits up to 10 m deep. A new GSC Atlantic database from more than 10,000 individual scours provides accurate and detailed information to guide such issues as depth of pipeline burial.

For example, any subsea facilities for Bjarni, the largest gas field in eastern Canada, must be designed for a typical iceberg scour event of 42-m width, 360-m length, and a 0.4-m scour depth. Significant variations in Labrador Shelf scour parameters occur according to water depth, seabed slope, and sediment type. Scour depths are shallower (mean 0.22 m) in sand on the banktops and deeper in softer, silty sediments within the marginal trough. Anomalously deep scours (mean 1.81 m) were found in soft muddy sediments within bedrock channels on the inner shelf, perhaps reflecting stronger forces driving the icebergs or more scour-able seabed sediments (Figure 2).

More difficult to pin down, however, is just how often iceberg scouring events occur. The seafloor is riddled with furrows and pits that have been accumulating over thousands of years. Repetitively mapping a seabed area over long-time intervals with sidescan or multibeam sonar is currently the only practical method of assessing iceberg scour frequency for a particular area. Repeat surveys establish iceberg scouring rates based on the number of new scours created over the time interval between surveys. In the absence of an operational iceberg tracking program, repetitive mapping is the only source of seabed data to constrain predictive numerical scour models. In 2006, GSC Atlantic collected repeat survey data over three sidescan surveys from the 1980s on Saglek Bank (Figure 3). As expected, scour frequency was highest in the shallowest and most northward of the three sites. In the central part of Saglek Bank in 120 m of water, 14 new scour events occurred over 27 years in a seabed area of 12.4 km^2. This means that a scour would occur once every 25 years over a square kilometre of seabed. At that rate, it would have taken more than 800 years to accumulate all the scours seen on the seafloor. In fact, it is likely that scouring has been occurring for much longer, so either the long-term scour rate is lower or, more likely, scours are being eroded by currents and organisms and gradually disappear. The new GSC Atlantic repetitive mapping data are valuable as they will be used to calibrate numerical models that will provide scour rate estimates for the entire shelf, not just for very small repetitively mapped areas. This research will provide critical geoscience understanding to ensure that future design plans for offshore development are safe, properly situated, and cost-effectively constructed and installed.

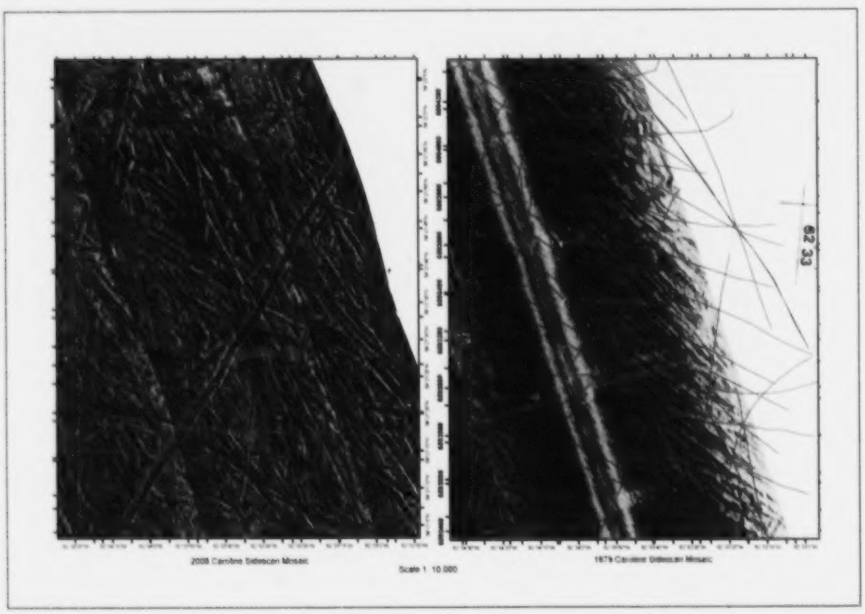


Figure 3. Comparison of scours mapped from 1982

Oil Fluorescence — A New Tool for Tracking Oil Spill Dispersion

Paul Kepkay, Jay Bugden, and Kenneth Lee

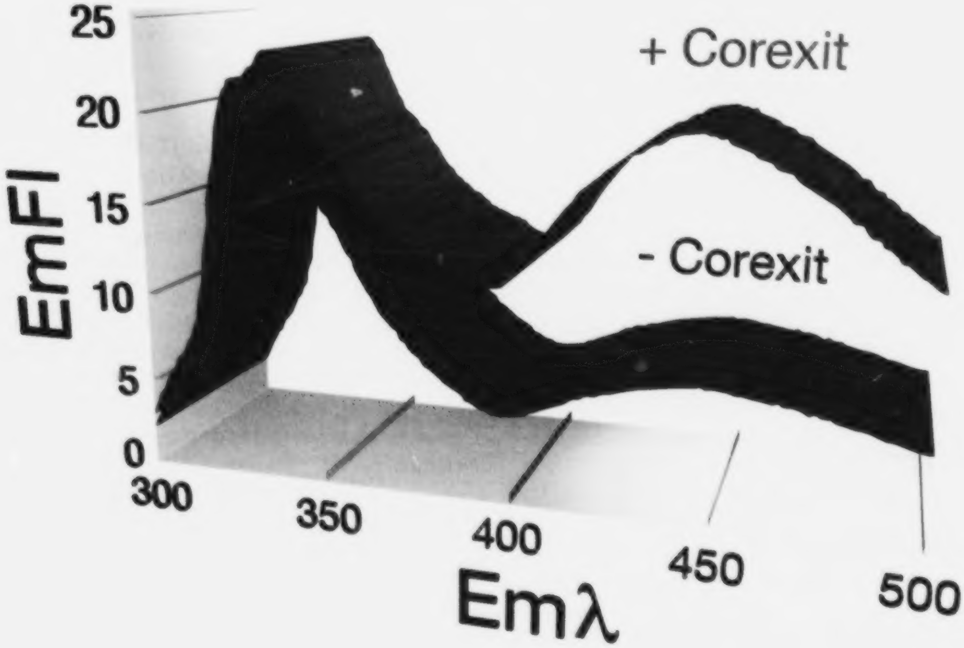


Figure 1. Graphic shows spectra of emission fluorescence intensity (EmFI) of Mesa crude oil dispersed in seawater with (red) and without (blue) Corexit 9500 as a chemical dispersant. Note that these two-dimensional spectra have been generated over a range of emission wavelengths (Em λ) by applying a single wavelength of ultraviolet light and how the addition of the dispersant strongly enhances fluorescence over a broad peak centered on an emission wavelength of 445 nm.

Oil spills in the ocean cause serious environmental damage if not remediated. To implement a practical remediation strategy, the spilled oil must be tracked and monitored as a slick is dispersed down into the water column. Natural dispersion and remediation are generally limited by environmental factors, and can often be enhanced by the addition of chemical dispersants and suspended sediment. The United States Coast Guard (USCG) has given high priority to oil slick dispersion operations in its Special Monitoring of Applied Response Technologies (SMART) program. An integral part of SMART is the requirement for new fluorescence techniques to monitor the dispersion process. DFO's Centre for Offshore Oil, Gas and Energy Research (COOGER) is working with the USCG and a consortium of scientists to better apply fluorescence as a tool in the program.

ULTRAVIOLET FLUORESCENCE SPECTROSCOPY

COOGER has responded to the requirements of SMART by taking new advances in ultraviolet fluorescence spectroscopy (UVFS) and applying them to the ongoing problem of spill dispersion. UVFS is simply the application of ultraviolet (UV) light to a sample and the measurement of the fluorescence emitted in response to the light. It has already been shown to be a rapid and sensitive means of obtaining information on the composition and concentration of many organic compounds in seawater, and is a particularly useful tool because it does not require the extraction and concentration procedures typical of other techniques (such as gas chromatography). Two-dimensional (2D) emission spectra of oil fluorescence in seawater are characterized by two peaks at 340 and 445 nm when UV light with a wavelength of 280 nm is shone on oil suspended in seawater (Figure 1). The addition of chemical dispersant to this system enhances fluorescence at 445 nm to the level where it can be almost equal to the fluorescence emitted at 340 nm (Figure 1). This preferential increase at 445 nm is the result of dispersant acting on higher molecular weight fractions of the oil, increasing their combined aqueous concentration by increasing the number of small droplets dispersed into the water column.

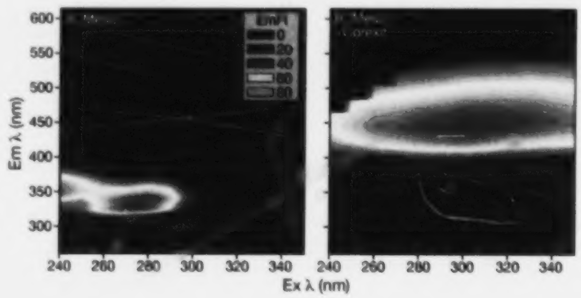


Figure 2. Graphics are contour plots of three-dimensional (3D) spectra of Mesa crude oil dispersed in seawater (A) and dispersed with the chemical dispersant, Corexit 9500, in seawater (B). Note the strong enhancement of emission fluorescence intensity (EmFI) centred on an emission wavelength of 445 nm over a broad range of excitation wavelengths (Em λ) applied to the samples.

EXCITATION-EMISSION MATRIX SPECTROSCOPY

Excitation-emission matrix spectroscopy (EEMS) is an extension of 2D UVFS, where emission fluorescence is measured in response to UV light shone on a sample over a range of wavelengths rather than just one. New laboratory equipment obtained by COOGER has allowed EEMS to be applied to suspensions of oil in seawater to obtain unique, three-dimensional (3D) fingerprints of the oil. More importantly, these 3D spectra have allowed the effect of chemical dispersants on oil fluorescence to be defined in greater detail.

In effect, the 3D spectrum obtained by EEMS is the unique fingerprint of an oil, and also provides a definitive picture of the effect of chemical dispersant on the fingerprint. In Figure 2, the contour plots of 3D spectra highlight just how strongly emission fluorescence is enhanced at 445 compared to 340 nm. This has evolved into the idea that the effect of chemical dispersant on 3D spectra can be expressed simply as a ratio between fluorescence at 340 nm divided by fluorescence at 445 nm. This, in turn, leads to an important conclusion: emission ratios can be used as direct indices of whether oil is dispersed effectively or poorly.

FUTURE DEVELOPMENTS FOR FIRST RESPONDERS

More important than the utilization of an emission ratio to determine the extent of oil dispersion is the fact that the ratio can be applied without having to measure oil concentration. This means that a field instrument can be developed to determine the ratio continuously, in real time, and in situ without external calibration. This is a distinct advantage for Coast Guard crew acting as first responders during a spill emergency. An emission-ratio instrument that is capable of tracking oil dispersion in situ provides the up-front information required for the rapid implementation of a remediation strategy. This instrument will be developed as a collaborative project between scientists at COOGER and colleagues in private industry.

Replenishment of Labrador Sea Water to the Ocean Conveyor Belt in 2008

Igor Yashayaev and John Loder

The Labrador Sea is one of the primary areas in the world's oceans where an important global ocean circulation pattern called the "ocean conveyor belt" or "meridional overturning circulation" is replenished by the episodic sinking of cold, dense water to intermediate or greater depths. Strong atmospheric cooling during severe winters makes this sinking particularly massive, mixing surface waters with underlying layers and producing a water mass known as Labrador Sea Water (LSW). After sinking to depths of 800-2,400 m (the penetration depth and horizontal extent of this process depend on the severity of the winter and ocean conditions) LSW spreads equatorward and eastward, becoming the major intermediate-depth water mass in the northern North Atlantic. The portion that flows equatorward in the North Atlantic's Deep Western Boundary Current is an important component of the ocean conveyor belt which transfers biogeochemical substances, heat, and fresh water between equatorial and polar regions, thereby regulating the Earth's climate and making our planet habitable.

The North Atlantic has a pronounced east-west temperature gradient (Figure 1) associated with its warm subtropical and cool subpolar gyres, atmospheric cooling, and Arctic outflows. Relatively warm upper-ocean waters are carried northeastward by the Gulf Stream system, while cooler waters are transported equatorward along the western boundary by the Labrador Current, the intermediate-depth flow of LSW, and the Deep Western Boundary Current at greater depth (Figure 2). Changes in the overall three-dimensional circulation pattern, associated with the upper-ocean gyres and the production rates of the deep and intermediate waters such as the LSW, have been an important factor in past glacial climate variability and are expected to be an important factor to the rate and impact of global and regional climate change under greenhouse warming.

DFO's Ocean Sciences and Ecosystem Research divisions have been conducting annual oceanographic surveys of the Labrador Sea for the past two decades as part of DFO's ocean climate monitoring program. (See *BIO 2007 In Review*.) Physical, chemical, and biological measurements are made each spring along a line (referred to as AR7W) extending from Labrador to Greenland (Figure 1). Since 2002, these observations have been comple-

mented by temperature and salinity profiles from drifting floats deployed in the international Argo program (www.argo.net). These floats drift for several years and regularly (typically, every 10 days) transmit data from a profile extending from a depth of 2,000 m to the ocean surface, providing year-round temporal and improved spatial coverage. The datasets from the May 2008 survey on the AR7W line and Argo profiles have revealed that the winter of 2007-2008 was special in the Labrador Sea region: dense surface water sank to depths of about 1,600 m, resulting in the production of a large volume of LSW. This particular year-class of LSW is referred to as LSW_{2008}. Its production appears to have been associated with a combination of atmospheric and oceanographic factors, with greater-than-normal atmospheric cooling over the northern North Atlantic playing a major role.

The extent of LSW_{2008} production is illustrated in Figure 4 through comparison of the temperatures observed on the AR7W line in the May 2007 and May 2008 surveys. The May 2008 survey shows a deeper and cooler mixed layer over the depth range of 400–1,600 m in the west-central Labrador Sea, slightly colder than 3.4°C. The Argo temperature profiles (Figure 5) indicate that this layer was gradually formed by vertical overturning and cool (dense) water sinking to increasing depths during January-March 2008. A relatively cold (dark blue in Figure 5) homogeneous mixed layer deepened from an initial depth of about 100 m in January to a depth of about 1,600 m in late March. After this, the profiles show the seasonal development of a relatively warm near-surface layer such that, by the time of the AR7W survey in May, the newly formed LSW_{2008} was isolated from interaction with the atmosphere.

The Argo profiles provide an unprecedented real-time view of the seasonal evolution of temperature and salinity in the upper 2,000 m of the Labrador Sea, as well as elsewhere in the global ocean. A clear seasonal cycle with a winter period of mixed-layer deepening to varying depths, followed by upper-ocean warming during spring-summer, is apparent in Figure 5. The profiles show that the deepening to 1,600 m in 2008 was greater than in any other year during the 2002-2008 Argo observation period. The prior peak deepening during this period

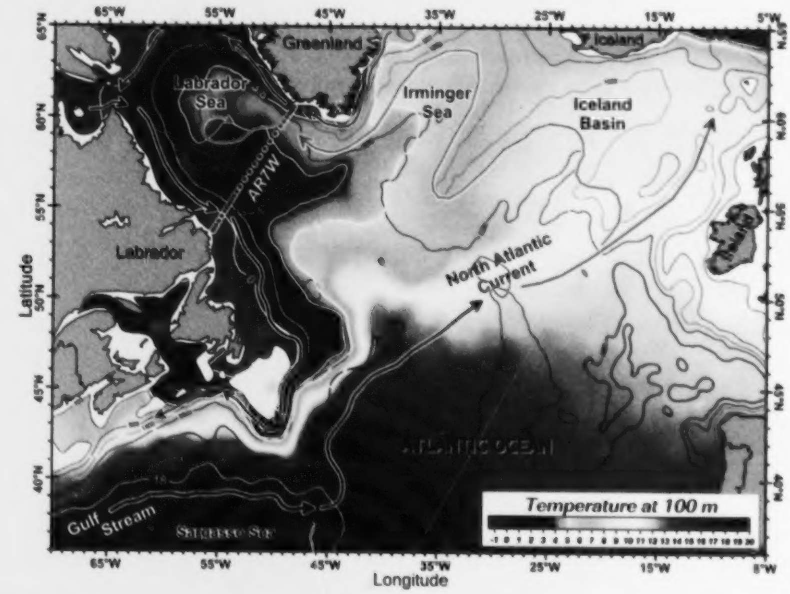


Figure 1. Distributions of temperature (°C) at 100 m below the surface in the northern North Atlantic: the red-tinted arrows indicate the Gulf Stream and associated North Atlantic Current which transport warm surface water northward; the blue arrows indicate the currents around Greenland and Labrador which carry relatively cold water southward; the red circles indicate the sampling sites on the AR7W monitoring line.

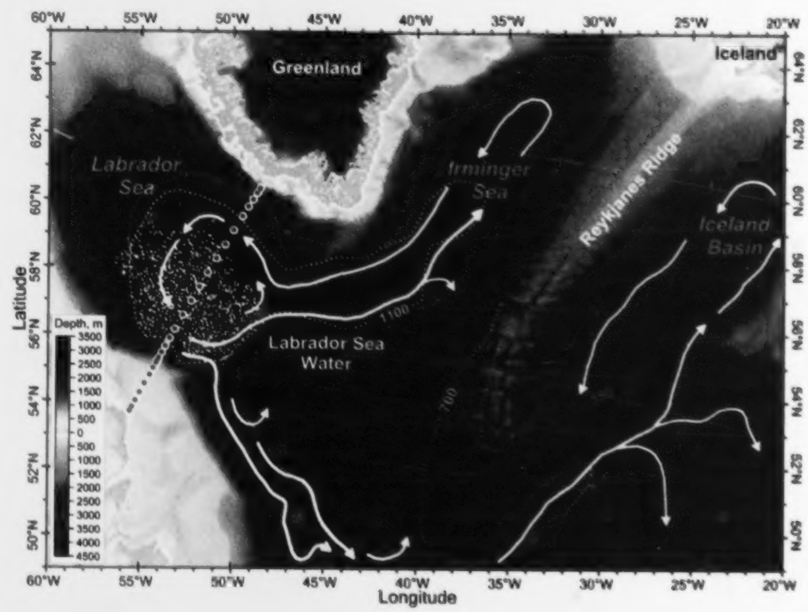


Figure 2. Map of the subpolar North Atlantic shows its major topographic features, the circulation pathways of LSW (yellow arrows), the Deep Western Boundary Current (magenta arrows), and the AR7W line. The colour coding indicates water depths and land elevation (in metres). The dashed lines represent the thickness of LSW_{1994} based on several oceanographic surveys conducted in the region during three years (1995-1997) that followed the year of its formation in the winter of 1993-1994. The red circles indicate the oceanographic stations on the Labrador Sea repeat hydrography line (AR7W). The white dots indicate the locations of the Argo profiles used to construct the time series in Figure 5.

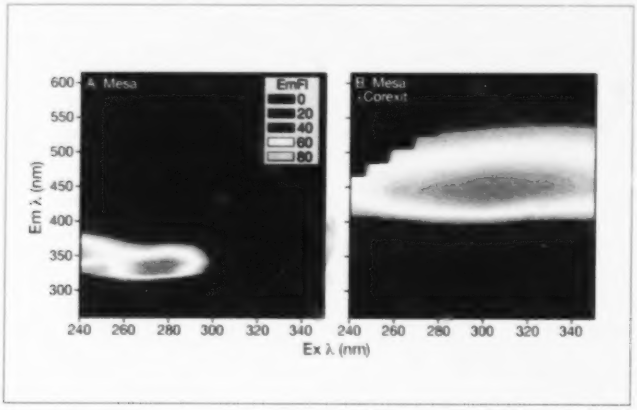


Figure 2. Graphics are contour plots of three-dimensional (3D) spectra of Mesa crude oil dispersed in seawater (A) and dispersed with the chemical dispersant, Corexit 9500, in seawater (B). Note the strong enhancement of emission fluorescence intensity (EmFI) centred on an emission wavelength of 445 nm over a broad range of excitation wavelengths (Em λ) applied to the samples.

EXCITATION-EMISSION MATRIX SPECTROSCOPY

Excitation-emission matrix spectroscopy (EEMS) is an extension of 2D UVFS, where emission fluorescence is measured in response to UV light shone on a sample over a range of wavelengths rather than just one. New laboratory equipment obtained by COOGER has allowed EEMS to be applied to suspensions of oil in seawater to obtain unique, three-dimensional (3D) fingerprints of the oil. More importantly, these 3D spectra have allowed the effect of chemical dispersants on oil fluorescence to be defined in greater detail.

In effect, the 3D spectrum obtained by EEMS is the unique fingerprint of an oil, and also provides a definitive picture of the effect of chemical dispersant on the fingerprint. In Figure 2, the contour plots of 3D spectra highlight just how strongly emission fluorescence is enhanced at 445 compared to 340 nm. This has evolved into the idea that the effect of chemical dispersant on 3D spectra can be expressed simply as a ratio between fluorescence at 340 nm divided by fluorescence at 445 nm. This, in turn, leads to an important conclusion: emission ratios can be used as direct indices of whether oil is dispersed effectively or poorly.

FUTURE DEVELOPMENTS FOR FIRST RESPONDERS

More important than the utilization of an emission ratio to determine the extent of oil dispersion is the fact that the ratio can be applied without having to measure oil concentration. This means that a field instrument can be developed to determine the ratio continuously, in real time, and in situ without external calibration. This is a distinct advantage for Coast Guard crew acting as first responders during a spill emergency. An emission-ratio instrument that is capable of tracking oil dispersion in situ provides the up-front information required for the rapid implementation of a remediation strategy. This instrument will be developed as a collaborative project between scientists at COOGER and colleagues in private industry.

Replenishment of Labrador Sea Water to the Ocean Conveyor Belt in 2008

Igor Yashayaev and John Loder

The Labrador Sea is one of the primary areas in the world's oceans where an important global ocean circulation pattern called the "ocean conveyor belt" or "meridional overturning circulation" is replenished by the episodic sinking of cold, dense water to intermediate or greater depths. Strong atmospheric cooling during severe winters makes this sinking particularly massive, mixing surface waters with underlying layers and producing a water mass known as Labrador Sea Water (LSW). After sinking to depths of 800-2,400 m (the penetration depth and horizontal extent of this process depend on the severity of the winter and ocean conditions) LSW spreads equatorward and eastward, becoming the major intermediate-depth water mass in the northern North Atlantic. The portion that flows equatorward in the North Atlantic's Deep Western Boundary Current is an important component of the ocean conveyor belt which transfers biogeochemical substances, heat, and fresh water between equatorial and polar regions, thereby regulating the Earth's climate and making our planet habitable.

The North Atlantic has a pronounced east-west temperature gradient (Figure 1) associated with its warm subtropical and cool subpolar gyres, atmospheric cooling, and Arctic outflows. Relatively warm upper-ocean waters are carried northeastward by the Gulf Stream system, while cooler waters are transported equatorward along the western boundary by the Labrador Current, the intermediate-depth flow of LSW, and the Deep Western Boundary Current at greater depth (Figure 2). Changes in the overall three-dimensional circulation pattern, associated with the upper-ocean gyres and the production rates of the deep and intermediate waters such as the LSW, have been an important factor in past glacial climate variability and are expected to be an important factor to the rate and impact of global and regional climate change under greenhouse warming.

DFO's Ocean Sciences and Ecosystem Research divisions have been conducting annual oceanographic surveys of the Labrador Sea for the past two decades as part of DFO's ocean climate monitoring program. (See *BIO 2007 In Review*.) Physical, chemical, and biological measurements are made each spring along a line (referred to as AR7W) extending from Labrador to Greenland (Figure 1). Since 2002, these observations have been comple-

mented by temperature and salinity profiles from drifting floats deployed in the international Argo program (www.argo.net). These floats drift for several years and regularly (typically, every 10 days) transmit data from a profile extending from a depth of 2,000 m to the ocean surface, providing year-round temporal and improved spatial coverage. The datasets from the May 2008 survey on the AR7W line and Argo profiles have revealed that the winter of 2007-2008 was special in the Labrador Sea region: dense surface water sank to depths of about 1,600 m, resulting in the production of a large volume of LSW. This particular year-class of LSW is referred to as LSW_{2008}. Its production appears to have been associated with a combination of atmospheric and oceanographic factors, with greater-than-normal atmospheric cooling over the northern North Atlantic playing a major role.

The extent of LSW_{2008} production is illustrated in Figure 4 through comparison of the temperatures observed on the AR7W line in the May 2007 and May 2008 surveys. The May 2008 survey shows a deeper and cooler mixed layer over the depth range of 400–1,600 m in the west-central Labrador Sea, slightly colder than 3.4°C. The Argo temperature profiles (Figure 5) indicate that this layer was gradually formed by vertical overturning and cool (dense) water sinking to increasing depths during January-March 2008. A relatively cold (dark blue in Figure 5) homogeneous mixed layer deepened from an initial depth of about 100 m in January to a depth of about 1,600 m in late March. After this, the profiles show the seasonal development of a relatively warm near-surface layer such that, by the time of the AR7W survey in May, the newly formed LSW_{2008} was isolated from interaction with the atmosphere.

The Argo profiles provide an unprecedented real-time view of the seasonal evolution of temperature and salinity in the upper 2,000 m of the Labrador Sea, as well as elsewhere in the global ocean. A clear seasonal cycle with a winter period of mixed-layer deepening to varying depths, followed by upper-ocean warming during spring-summer, is apparent in Figure 5. The profiles show that the deepening to 1,600 m in 2008 was greater than in any other year during the 2002-2008 Argo observation period. The prior peak deepening during this period

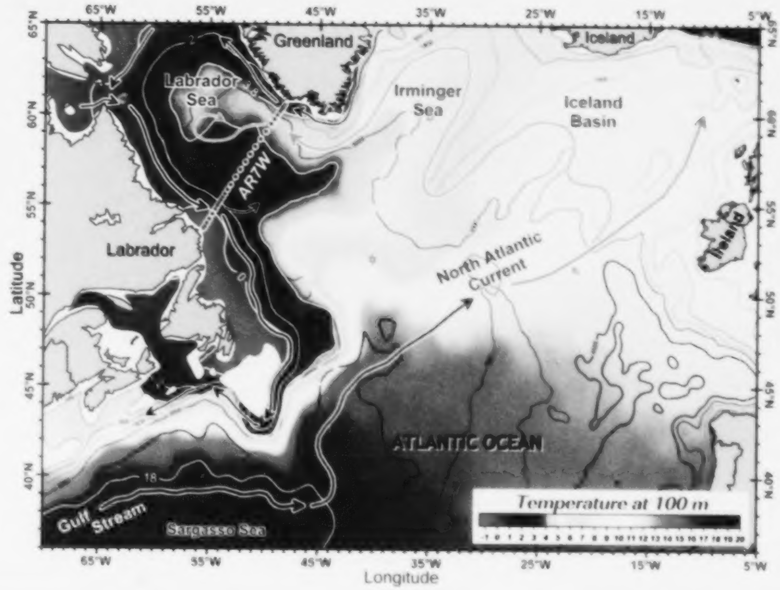


Figure 1. Distributions of temperature (°C) at 100 m below the surface in the northern North Atlantic: the red-tinted arrows indicate the Gulf Stream and associated North Atlantic Current which transport warm surface water northward; the blue arrows indicate the currents around Greenland and Labrador which carry relatively cold water southward; the red circles indicate the sampling sites on the AR7W monitoring line.

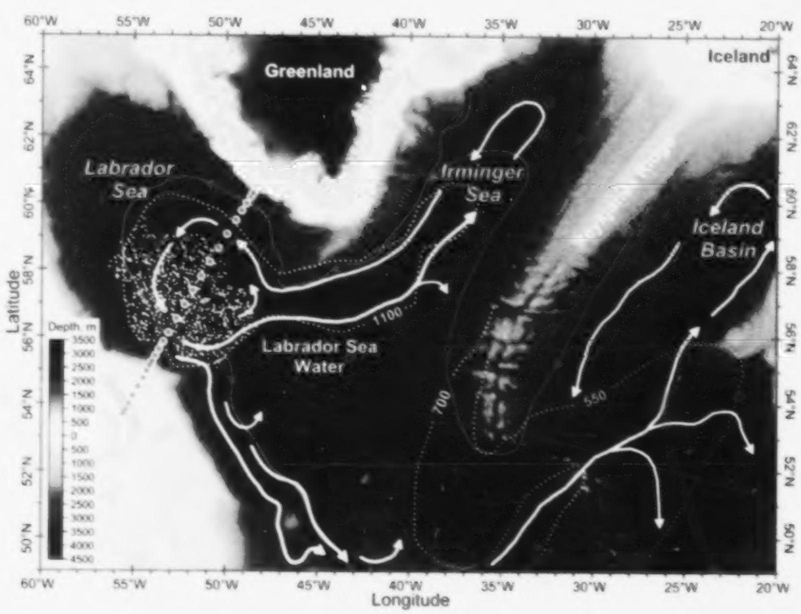


Figure 2. Map of the subpolar North Atlantic shows its major topographic features, the circulation pathways of LSW (yellow arrows), the Deep Western Boundary Current (magenta arrows), and the AR7W line. The colour coding indicates water depths and land elevation (in metres). The dashed lines represent the thickness of LSW_{1994} based on several oceanographic surveys conducted in the region during three years (1995-1997) that followed the year of its formation in the winter of 1993-1994. The red circles indicate the oceanographic stations on the Labrador Sea repeat hydrography line (AR7W). The white dots indicate the locations of the Argo profiles used to construct the time series in Figure 5.

occurred in 2003 when, after a succession of cold winters starting in 2000, sinking reached a depth of about 1,300 m. The profiles also show that this 2000-2003 year class of LSW, referred to as LSW_{2000}, gradually warmed and disappeared from the Labrador Sea during subsequent years when winters were relatively mild. A weak vertical gradient in temperature had developed over most of the Labrador Sea by 2007 (also see the 2007 AR7W section in Figure 4). The most recent Argo profiles (Figure 5) show that LSW_{2008} has already started to disappear (exit) from the region.

The time series of Labrador Sea temperature variability composed from the recent AR7W observations supplemented by less systematic observations dating back to 1970 (Figure 6) indicates that there have been remarkable changes over the past few decades. The most prominent of these changes was the formation of the voluminous LSW_{1994} class. This record cold, dense, and deep LSW class developed during the period between the late 1980s and mid-1990s, when successive severe winters caused the Labrador Sea to convect to 2,400 m. The dashed lines in Figure 2 represent the thickness of LSW_{1994} based on temperature and salinity observations collected in the region between 1995 and 1997. LSW_{1994} class declined over subsequent years, associated with the decreased strength of winter cooling combined with warmer and saltier waters entering the Labrador Sea from the other subpolar basins. The instrumental record presented in Figure 5 also indicates that the depth of LSW formation in 2008 was actually the largest since 1994 when LSW_{1994} was formed.

Figure 3a. A top float from a subsurface oceanographic mooring being secured on the deck of CCGS *Hudson* during a mooring recovery operation, Orphan Basin, May 2009 (image courtesy of Anthony Joyce)

There is clear evidence that the increased LSW production in 2008 resulted, at least in part, from an above-normal extraction of ocean heat into the atmosphere during the winter of 2007-2008. This was associated with cooler atmospheric temperatures over the North Atlantic than in recent years, consistent with the origin of previous periods of enhanced LSW production. It is noteworthy that the 2008 production occurred in spite of general warming in the Labrador Sea and globally over the past decade and a half, providing another reminder of the importance of inter-annual and other short-term weather variability to regional and short-term conditions in the atmosphere and the ocean.

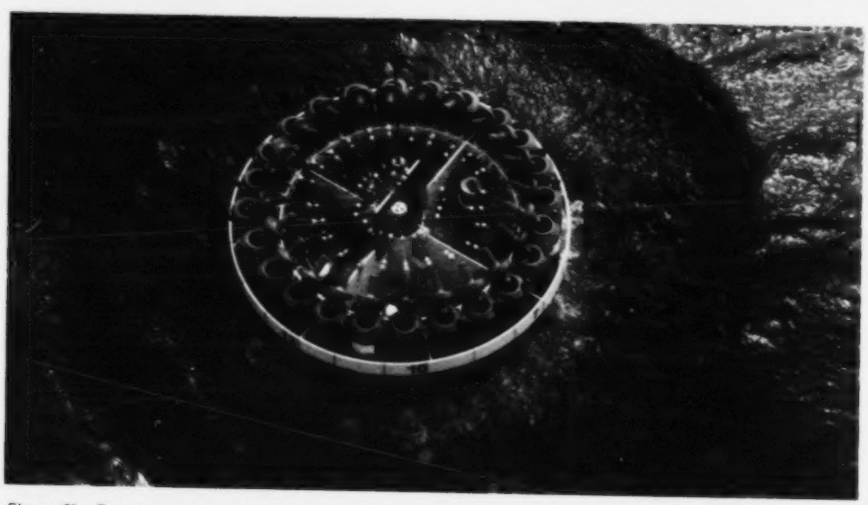


Figure 3b. Rosette system with water sampling "bottles" (around perimeter) and CTD system measuring key seawater properties (below surface and not visible) being lowered into water to do an oceanographic station in Orphan Basin of the Labrador Sea, May 2009 (image courtesy Igor Shkvorets)

Although the magnitude of the recent changes in LSW temperature is small, there is potential for a significant longer-term and larger-scale influence because of the large volume and heat capacity of the affected ocean waters, and of the role of LSW in the ocean conveyor belt. The regional replenishment of the conveyor belt by LSW_{2008}, and the ongoing renewal of deep waters flowing through the Labrador Sea, indicate

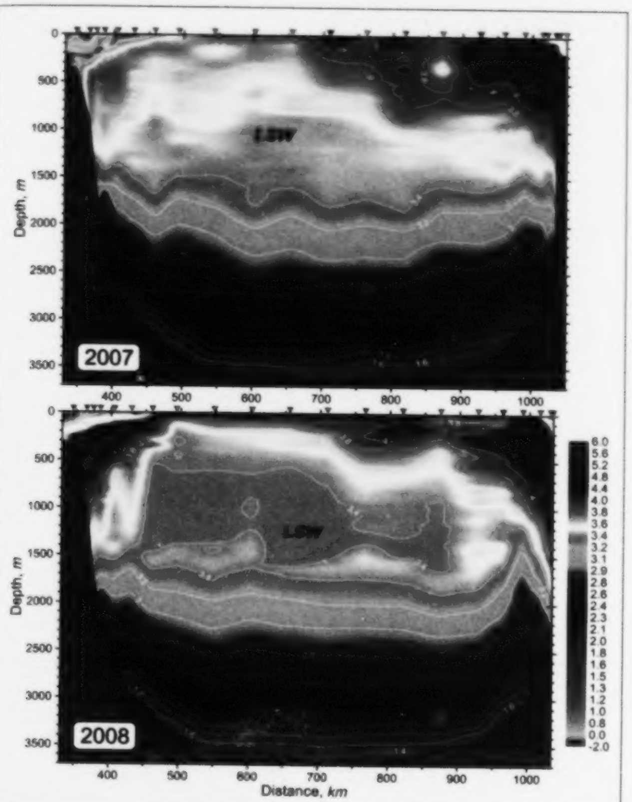


Figure 4. Shown are distributions of temperature (°C) on the AR7W line (Figures 1 and 2) in May 2007 (top) and May 2008 (bottom). The Labrador Shelf is on the left.

that the global conveyor belt is continuing to function. This ocean circulation pattern continues to mediate global warming and climate change through the redistribution of heat and carbon in the ocean, which is the primary reservoir for these important components of the global climate system. However, the degree to which this mediation is occurring and will continue to occur requires further study, including continued observations and understanding of the ocean in key areas like the Labrador Sea. The high-resolution spatial snapshots of the Labrador Sea's oceanographic and biogeochemical structure from the annual AR7W surveys together with the recent continual monitoring of its seasonal variability by the Argo program provide a much improved basis for the ongoing assessment of ocean climate variability and change in this important region.

BIBLIOGRAPHY

Azetsu-Scott, Kumiko, Glen Harrison, Erica Head, Ross Hendry, William Li, John Loder, Alain Vézina, Dan Wright, Igor Yashayaev, and Philip Yeats. Climate Variability and Change in the Northwest Atlantic, p. 4-11. *In* Judith Ryan [ed]. Bedford Institute of Oceanography 2007 In Review.

Lazier, John, Ross Hendry, Allyn Clarke, Igor Yashayaev, and Peter Rhines, 2002. Convection and restratification in the Labrador Sea, 1990-2000, Deep-Sea Res., 49A(10), 1819-1835.

Yashayaev, Igor, 2007. Hydrographic changes in the Labrador Sea, 1960-2005, Progress in Oceanography, 73(3-4), 10.1016/j.pocean.2007.04.015, 242-276.

Yashayaev, Igor, Hendrik van Aken, Penny Holliday, and Manfred Bersch, 2007. Transformation of the Labrador Sea Water in the Subpolar North Atlantic, Geophysical Research Letters, 34, L22605, doi:10.1029/2007GL031812.

Yashayaev, Igor, and John Loder, 2009. Enhanced production of Labrador Sea Water in 2008, Geophysical Research Letters, 36, L01606, doi:10.1029/2008GL036162.

Våge, Kjetil, Robert Pickart, Virginie Thierry, Giles Reverdin, Craig M. Lee, Brian Petrie, Tom A. Agnew, Amy Wong, and Mads H. Ribergaard, 2009. Surprising return of deep convection to the subpolar North Atlantic Ocean in winter 2007–2008, Nature Geoscience, 2.

ACKNOWLEDGEMENTS

The authors are grateful to their many colleagues who contributed to the successful execution of BIO's Labrador Sea surveys.

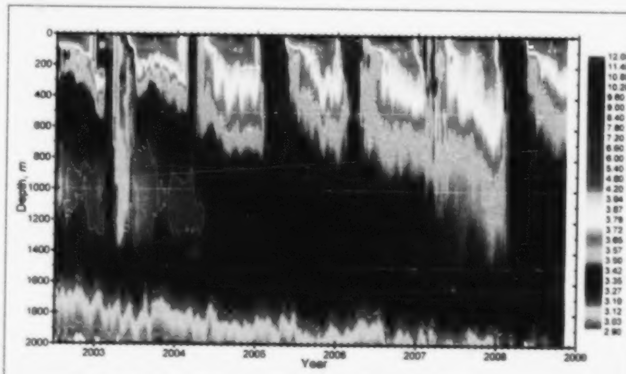


Figure 5. Seasonal-to-interannual development of temperature (°C) in the central Labrador Sea from Argo observations (Locations of the Argo profiles chosen for this compilation are shown in Figure 2.)

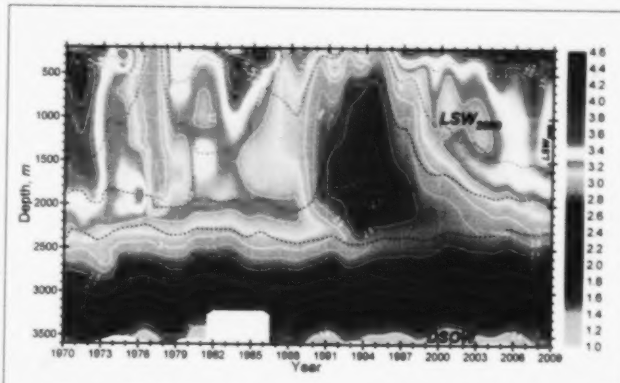


Figure 6. Time series of temperature (°C) in the central Labrador Sea, constructed from all available data with the exception of the Argo profiles: the dashed contours indicate seawater density and reflect changes in the density and volume of various LSW classes.

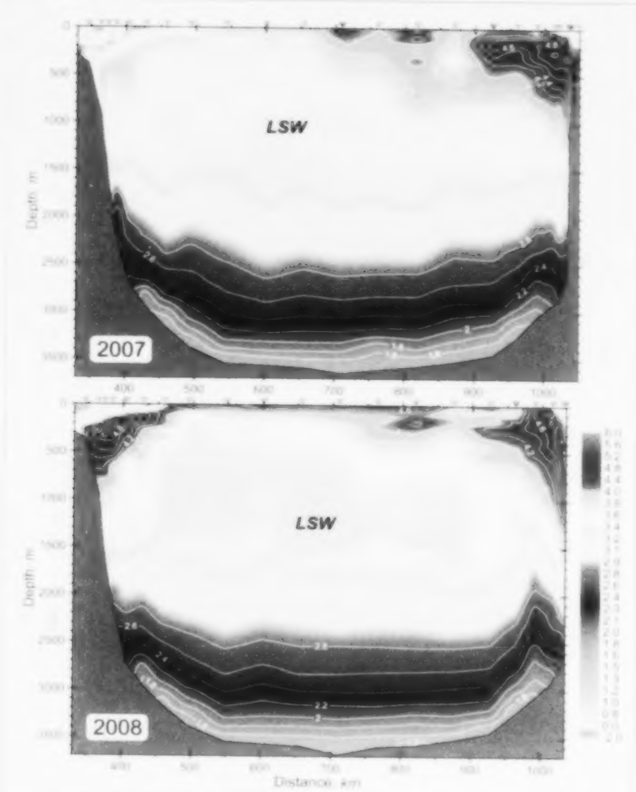


Figure 4. Shown are distributions of temperature (°C) on the AR7W line (Figures 1 and 2) in May 2007 (top) and May 2008 (bottom). The Labrador Shelf is on the left.

that the global conveyor belt is continuing to function. This ocean circulation pattern continues to mediate global warming and climate change through the redistribution of heat and carbon in the ocean, which is the primary reservoir for these important components of the global climate system. However, the degree to which this mediation is occurring and will continue to occur requires further study, including continued observations and understanding of the ocean in key areas like the Labrador Sea. The high-resolution spatial snapshots of the Labrador Sea's oceanographic and biogeochemical structure from the annual AR7W surveys together with the recent continual monitoring of its seasonal variability by the Argo program provide a much improved basis for the ongoing assessment of ocean climate variability and change in this important region.

BIBLIOGRAPHY

Azetsu-Scott, Kumiko, Glen Harrison, Erica Head, Ross Hendry, William Li, John Loder, Alain Vezina, Dan Wright, Igor Yashayaev, and Philip Yeats. Climate Variability and Change in the Northwest Atlantic, p. 4-11. In Judith Ryan [ed.] Bedford Institute of Oceanography 2007 In Review.

Lazier, John, Ross Hendry, Allyn Clarke, Igor Yashayaev, and Peter Rhines. 2002. Convection and restratification in the Labrador Sea, 1990-2000, Deep Sea Res., 49A(10), 1819-1835.

Yashayaev, Igor. 2007. Hydrographic changes in the Labrador Sea, 1960-2005, Progress in Oceanography, 73(3-4), 10.1016/j.pocean.2007.04.015, 242-276.

Yashayaev, Igor, Hendrik van Aken, Penny Holliday, and Manfred Bersch. 2007. Transformation of the Labrador Sea Water in the Subpolar North Atlantic, Geophysical Research Letters, 34, L22605, doi:10.1029/2007GL031812.

Yashayaev, Igor, and John Loder. 2009. Enhanced production of Labrador Sea Water in 2008, Geophysical Research Letters, 36, L01606, doi:10.1029/2008GL036162.

Våge, Kjetil, Robert Pickart, Virginie Thierry, Gilles Reverdin, Craig M. Lee, Brian Petrie, Tom A. Agnew, Amy Wong, and Mads H. Ribergaard. 2009. Surprising return of deep convection to the subpolar North Atlantic Ocean in winter 2007-2008, Nature Geoscience, 2.

ACKNOWLEDGEMENTS

The authors are grateful to their many colleagues who contributed to the successful execution of BIO's Labrador Sea surveys.

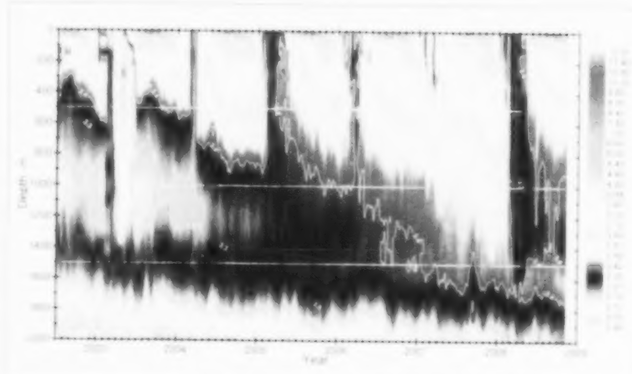


Figure 5. Seasonal to interannual development of temperature (°C) in the central Labrador Sea from Argo observations (Locations of the Argo profiles chosen for this compilation are shown in Figure 2.)

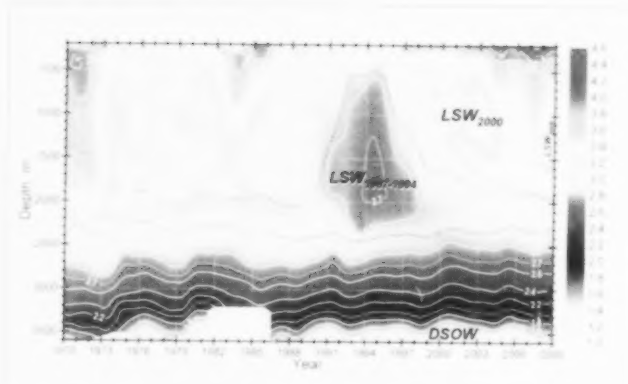


Figure 6. Time series of temperature (°C) in the central Labrador Sea constructed from all available data with the exception of the Argo profiles; the dashed contours indicate seawater density and reflect changes in the density and volume of various LSW classes.

Five Decades of Monitoring the Plankton in the Northwest Atlantic Ocean

Erica Head

In the mid-1920s, British scientist Sir Alister Hardy developed a new instrument, the continuous plankton recorder (CPR), to collect samples of plankton continuously during a ship's passage, rather than at fixed stations. Plankton are not uniformly distributed in the ocean, but are generally in patches near the surface and he wanted to map these patches to see if they coincided with schools of the fish that feed on them (e.g., herring and mackerel). In the 1930s, he modified his design to produce the version of the CPR that has been in regular use in the North Sea and North Atlantic Ocean, essentially unchanged, since 1946. The CPR survey in the North Atlantic samples along a series of routes on a regular basis and is operated by the Sir Alister Hardy Foundation for Ocean Science (SAHFOS), located in Plymouth, UK. (Figure 1).

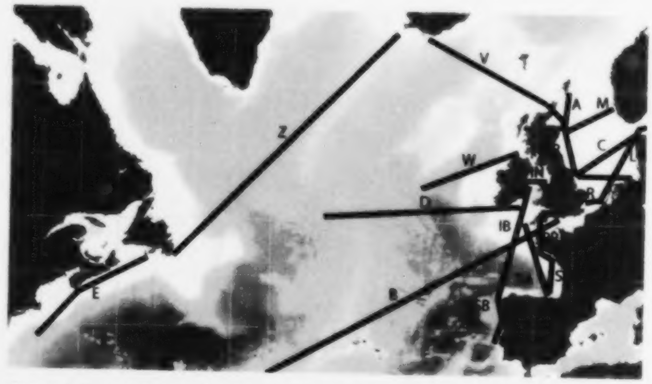


Figure 1. Regularly sampled continuous plankton recorder routes in the North Atlantic Ocean – figure courtesy of SAHFOS

Modern CPRs are about one metre in length and are made of stainless steel (Figure 2a). Because of their rugged design they can be towed by merchant ships at speeds of up to 25 knots and can be deployed and recovered in rough seas. The route between Reykjavik, Iceland, and the Canadian continental shelf was towed for the first time in 1957 and currently, routes from Reykjavik to St John's NL (the Z line) and from St John's to the New England coast (the E line) are towed every month by the containership *Reykjafoss* (Figure 3).

The CPR works by filtering water, which enters through a small opening at the front of the instrument, through a moving filter band of silk of mesh size 0.27 mm, which collects the plankton. This filtering gauze is pressed against a second one, with the plankton sandwiched between them, and the two are then wound on to a spool in a storage tank containing a preservative (formalin). The winding mechanism is via a system of gears powered by an internal propeller driven by the CPR's forward movement (Figure 2b).

The internal mechanism (plankton gauzes, rollers, and storage tank) is a self-contained cartridge that is loaded with the filtering silk in the laboratory in Plymouth. One band of gauze can cover 500 nautical miles, so that on the route between Reykjavik and New England (about 2,000 nautical miles) the ship is supplied with several cartridges, which are loaded into and removed from the CPR one after another. On return to the laboratory, silks are removed from the cartridges and cut into samples representing 10 nautical miles of towing. The samples are then analysed using standard procedures.

The Z and E towing lines together generate about 1,300 samples per year, which is roughly one quarter of the total number of samples collected by the entire North Atlantic CPR survey. DFO provides about 40% of the funds needed to operate this route in a joint project agreement with SAHFOS. SAHFOS is responsible for maintaining all equipment, for CPR deployments and recoveries, for shipping gear from and to their laboratory, and for sample analysis. DFO is provided with the data at the end of each year for the previous year's samples.

CPR sampling in the North Atlantic has covered such a large area for such a long period of time that it has allowed scientists to investigate issues that could not have been addressed in any other way. One such issue is the impact of climate change on plankton diversity and community structure. In the Northeast Atlantic, CPR sampling has shown a northward shift of warm-temperate zooplankton species in areas between the Bay of Biscay and the north of Scotland as temperatures have warmed over the past few decades (Beaugrand et al. 2002). As well, warming in the North Sea has been accompanied by the northward retreat of a previously dominant northern species, the copepod *Calanus finmarchicus* (Figure 5). *C. finmarchicus* eggs and young naupliar stages are important food sources for cod larvae, and the decline of the species in the North Sea is thought to be linked to a decrease in cod recruitment (Beaugrand et al. 2003).

There has been CPR sampling along the Z line since 1957 and along the E line since 1960, but there were missing months in some years, missing years in some decades, and there was no sampling on the E line in the 1980s. Because of these gaps, in order to examine how distributions have changed over time, data from sampled months and years within a decade were combined, first to give average monthly values, and then average annual values for each decade and for different regions of the Z and E lines.

In the Northwest Atlantic, *Calanus finmarchicus* is the dominant zooplankton species in CPR samples from the Z and E routes, in both Canadian shelf waters and the deep ocean. *C. finmarchicus* are counted in two categories in CPR samples: one corresponds to smaller (<2 mm) young stage copepodites (C1-4) and the other to larger (>2 mm) late stage copepodites (C5-6). Over the decades the highest abundance recorded for C1-4 *C. finmarchicus* was in the 1960s on the part of the Z line that crosses the Newfoundland Shelf. This value has decreased substantially since then and currently the abundance of C1-4 *C. finmarchicus* is similar in all areas, except near Iceland, where abundance has decreased steadily over the decades and is now at a very low level. The abundance of late stage (C5-6) *C. finmarchicus* has also decreased in the Newfoundland Shelf area, but to a lesser extent. C5-6 *C. finmarchicus* abundance has generally been highest in the central Northwest Atlantic between 35 and 45° W, where it

Figure 2a. Deploying a CPR – photo courtesy of SAHFOS

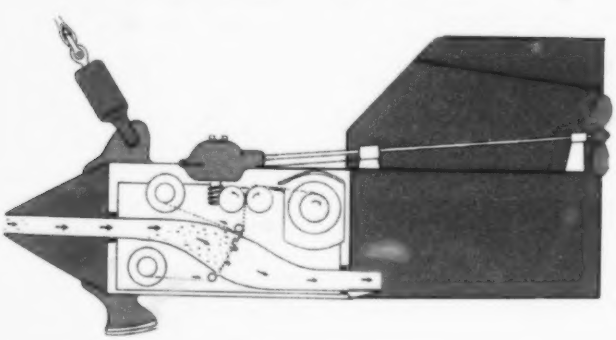


Figure 2b. Cutaway view of a CPR – figure courtesy of SAHFOS

has increased over time; changes elsewhere have not been large. Two Arctic *Calanus* species (*Calanus glacialis* and *Calanus hyperboreus*) have always had their highest abundances in the Newfoundland Shelf area, which is not surprising since this area is strongly influenced by the Labrador Current, which brings Arctic water south from Hudson Strait and Davis Strait. Their abundances in this area increased dramatically between the 1970s and the 1990s, decreasing somewhat in the 2000s.

In the context of the Northwest Atlantic, *C. finmarchicus* is a southern species, whereas in the Northeast Atlantic it is a northern species. Thus, in the Newfoundland Shelf area the decrease in abundance of *C. finmarchicus* species and the increases in abundance of the northern Arctic species seem to show the opposite pattern to the one seen in the Northeast Atlantic, i.e., a southward shift of northern species. There, the changes in abundance and distribution were linked to ocean warming. On the Newfoundland Shelf, annual average surface temperatures were very similar in the 1970s and 1990s, when the abundance of Arctic *Calanus* increased, so that the abundance changes do not seem to be related to temperature changes. Arctic water is fresher than water from other sources so that salinity (saltiness) can give an idea of the relative input of Arctic water to the Newfoundland Shelf. Salinities in the surface waters decreased between the 1960s and the 1990s, but increased in the 2000s. This suggests that the abundance of the Arctic species might be linked to the input of Arctic water.

Phytoplankton levels in the Northwest Atlantic have also changed over the last few decades. Large phytoplankton species, such as diatoms and dinoflagellates (Figure 6) are retained quite efficiently on the CPR gauze. Small species can pass through, but some still get absorbed, so that both large and small species contribute to the phytoplankton colour index (PCI), which is an index of total phytoplankton abundance assessed by observing the colour of freshly cut sample gauzes. The PCI was slightly higher in Canadian shelf waters than in deep ocean areas in the 1960s and the 1970s, but between the 1970s and the 1990s it increased dramatically in shelf waters and stayed high in the 2000s, while showing no real changes

Figure 3. The containership *Reykjafoss* tows a CPR between Iceland and New England. Photo courtesy of SAHFOS

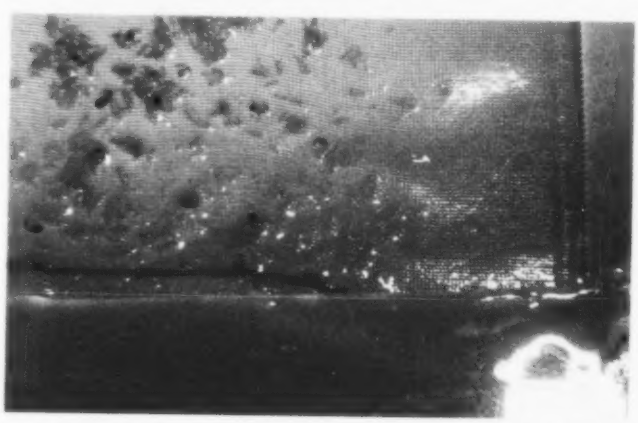
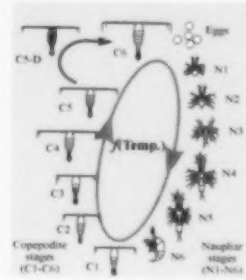


Figure 4. Plankton sample on a CPR gauze: this sample contains the plankton from 3 m³ (3,000 litres). Photo courtesy of SAHFOS

Figure 5. A female *Calanus finmarchicus* copepod with a clutch of newly laid eggs (body length: 2.8 mm)

Female *Calanus finmarchicus* release eggs into the near-surface layers of the ocean in spring, and these hatch and grow up through six naupliar stages and five copepodite stages over the late spring and summer. The females either die or are eaten by predators during spring and summer. Growth and development through each stage requires the shedding (moulting) of one outer casing (exoskeleton) and the formation of another larger one, as occurs in other crustacea, such as lobsters, crabs, and shrimp. When individuals reach the pre-adult stage, the fifth copepodite (C5) stage, in late summer or fall, they swim to depths as deep as 1,500 m, to spend the winter in an inactive resting state. The following spring, the C5s moult to adulthood, into males or females; the adults mate and return to the surface to start the cycle again. Figure courtesy of Bruno Zakardjian, Université du Sud Toulon-Var



in the deep ocean. The pattern for diatom abundance is similar, where the diatom category is the sum of all enumerated diatom species. Dinoflagellate abundance increased at the same time, but only in Newfoundland Shelf waters.

The causes for the variations in *Calanus* and phytoplankton abundance in the Northwest Atlantic over the decades are not entirely clear, but any links to environmental changes will become easier to identify as more data are accumulated. As well, continued CPR sampling will allow us to investigate other issues related to climate change that have not been discussed here. One such issue is ocean acidification. This is occurring because of increased uptake of carbon dioxide by the oceans, due to its build-up in the atmosphere. Colder, fresher waters, such as those of the Northwest Atlantic, are most susceptible to acidification and, as it increases, it will reach a point where it impacts members of the plankton, primarily those that have body parts made of calcium carbonate, because these can dissolve if the water is acidic enough (Figure 7). This point has not been reached yet, but continued CPR sampling will allow us to observe it as it arrives.

We have certainly moved on from Sir Alister Hardy's initial desire to see if patches of plankton are associated with schools of plankton-eating fish.

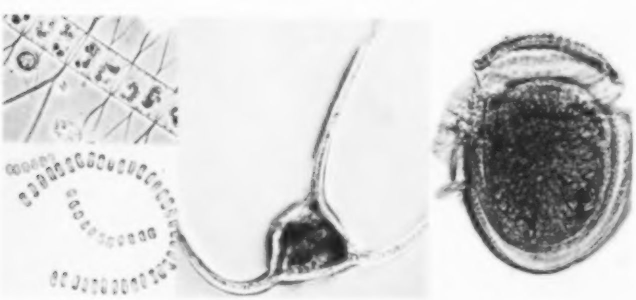


Figure 6. Diatoms from Atlantic Canadian coastal waters, from left: *Chaetoceros discipiens* (top); *Thalassiosira nordenskjoldii* (bottom); *Ceratium longipes*; and *Dionphysis rotundatum*

For further information on the Sir Alister Hardy Foundation for Ocean Science (SAHFOS) please visit their website at (www.sahfos.ac.uk).

BIBLIOGRAPHY

Beaugrand, G., P.C. Reid, F. Ibañez, J.A. Lindley, and M. Edwards.(2002) Reorganization of North Atlantic marine copepod biodiversity and climate. Science. 296, 1692-1694.

Beaugrand, G., K.M. Brander, J.A. Lindley, S. Soissi, and P.C. Reid. (2003) Plankton effect on cod recruitment in the North Sea. Nature. 426, 661-664.

Figure 7a. A coccolithophore *Coccolithus pelagicus* (~0.010 mm diameter) with its covering of calcium carbonate plates – image courtesy of Jeremy Young, Natural History Museum

Figure 7b. A foram, *Orbulina universa*, a sand-grain sized, single-chambered test (with calcium carbonate shell) surrounded by delicate spines – image courtesy of Howard Spero, University of Calfornia

Figure 7c. A pteropod or planktonic snail, *Limacina helicina*, with its calcium carbonate shell (shell length up to 3 mm) – image courtesy of Russ Hopcroft, University of Alaska

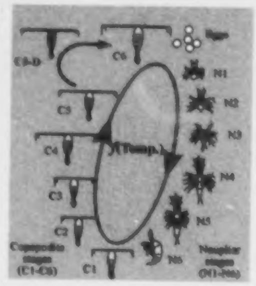
Figure 5. A female *Calanus finmarchicus* copepod with a clutch of newly laid eggs (body length: 2.8 mm)

in the deep ocean. The pattern for diatom abundance is similar, where the diatom category is the sum of all enumerated diatom species. Dinoflagellate abundance increased at the same time, but only in Newfoundland Shelf waters.

The causes for the variations in *Calanus* and phytoplankton abundance in the Northwest Atlantic over the decades are not entirely clear, but any links to environmental changes will become easier to identify as more data are accumulated. As well, continued CPR sampling will allow us to investigate other issues related to climate change that have not been discussed here. One such issue is ocean acidification. This is occurring because of increased uptake of carbon dioxide by the oceans, due to its build-up in the atmosphere. Colder, fresher waters, such as those of the Northwest Atlantic, are most susceptible to acidification and, as it increases, it will reach a point where it impacts members of the plankton, primarily those that have body parts made of calcium carbonate, because these can dissolve if the water is acidic enough (Figure 7). This point has not been reached yet, but continued CPR sampling will allow us to observe it as it arrives.

We have certainly moved on from Sir Alister Hardy's initial desire to see if patches of plankton are associated with schools of plankton-eating fish.

Figure 6. Diatoms from Atlantic Canadian coastal waters, from left: *Chaetoceros discipiens* (top); *Thalassiosira nordenskjoldii* (bottom); *Ceratium longipes*; and *Dionphysis rotundatum*



Female *Calanus finmarchicus* release eggs into the near-surface layers of the ocean in spring, and these hatch and grow up through six naupliar stages and five copepodite stages over the late spring and summer. The females either die or are eaten by predators during spring and summer. Growth and development through each stage requires the shedding (moulting) of one outer casing (exoskeleton) and the formation of another larger one, as occurs in other crustacea, such as lobsters, crabs, and shrimp. When individuals reach the pre-adult stage, the fifth copepodite (C5) stage, in late summer or fall, they swim to depths as deep as 1,500 m, to spend the winter in an inactive resting state. The following spring, the C5s moult to adulthood, into males or females; the adults mate and return to the surface to start the cycle again. Figure courtesy of Bruno Zakardjian, Université du Sud Toulon-Var

For further information on the Sir Alister Hardy Foundation for Ocean Science (SAHFOS) please visit their website at (www.sahfos.ac.uk).

BIBLIOGRAPHY

Beaugrand, G., P.C. Reid, F. Ibañez, J.A. Lindley, and M. Edwards.(2002) Reorganization of North Atlantic marine copepod biodiversity and climate. Science. 296, 1692-1694.

Beaugrand, G., K.M. Brander, J.A. Lindley, S. Soissi, and P.C. Reid. (2003) Plankton effect on cod recruitment in the North Sea. Nature. 426, 661-664.

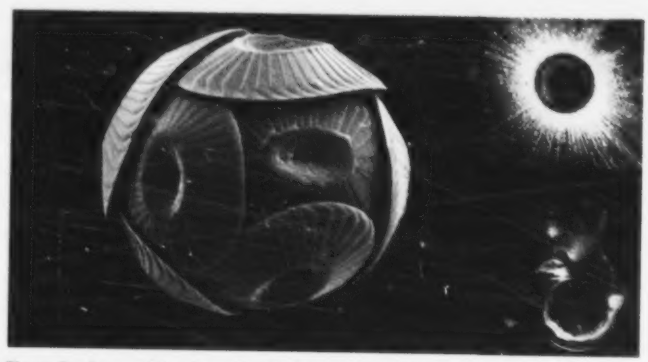


Figure 7a. A coccolithophore *Coccolithus pelagicus* (~0.010 mm diameter) with its covering of calcium carbonate plates – image courtesy of Jeremy Young, Natural History Museum

Figure 7b. A foram, *Orbulina universa*, a sand-grain sized, single-chambered test (with calcium carbonate shell) surrounded by delicate spines – image courtesy of Howard Spero, University of Calfornia

Figure 7c. A pteropod or planktonic snail, *Limacina helicina*, with its calcium carbonate shell (shell length up to 3 mm) – image courtesy of Russ Hopcroft, University of Alaska

Integrating New and Old Tagging Technologies for Atlantic Halibut

Shelley Armsworthy and Kurtis Trzcinski

Potentially reaching more than 2.5 m in length and 300 kg in weight, the Atlantic halibut is the largest of the flatfishes and one of the most economically important, yet biologically misunderstood, groundfish species in the Canadian Atlantic Ocean. The species ranges widely over the continental shelf and slopes of the Atlantic Ocean, but the distribution of individual populations is unknown. Although two management areas (stocks) for Atlantic halibut are recognized in Canadian waters – one within the Gulf of St. Lawrence and one occupying inshore and offshore waters of the Scotian Shelf and southern Grand Banks – the biological basis for this separation is questionable. Conventional tagging studies indicate Atlantic halibut move extensively throughout the Canadian North Atlantic, including well outside of Canada's Economic Exclusion Zone (EEZ), commonly referred to as the 200-mile limit. It is possible that halibut located outside Canadian management areas, including United States waters, the Flemish Cap, and waters north of Newfoundland, might be part of the same stock. Maine's Department of Marine Resources recently reported similar large movements and, in particular, found 28% of tags applied in nearshore Maine waters were recaptured in Canadian waters. However, no halibut tagged in Canadian waters has ever been caught in US waters. These results have raised concerns among US fishers and regulatory agencies, leading to the suggestion that Atlantic halibut should be treated as a transboundary stock, whereby management responsibilities would be shared by the United States and Canada.

Given the above uncertainties about stock distribution and stock mixing with the United States, research was urgently required. From 2006 to 2008, a conventional tag-recapture study of halibut on the Scotian Shelf and southern Grand Banks was jointly established by DFO Science and the Atlantic Halibut Council (AHC), which includes members from the halibut fishing industry. Tagging was conducted as part of the annual Halibut Long Line Survey – a survey that was developed collaboratively by industry and DFO Science in 1998 to monitor the Atlantic halibut stock throughout the Scotian Shelf and southern Grand Banks.

Unlike previous halibut tagging studies that were conducted opportunistically, the new tag-recapture study was designed not only to detect movement patterns, but also to estimate the level of exploitation by commercial fishing. Movement patterns give some indication about migration routes and can be used to confirm or redefine a stock management area. Exploitation rate is used to gauge if the stock is being harvested at an appropriate level, and is estimated by releasing a known number of tagged fish and determining the proportion recaptured.

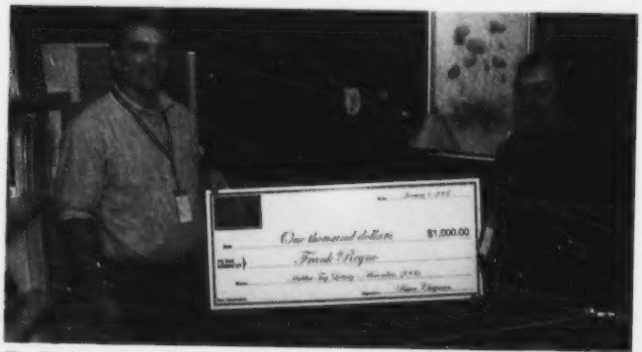
Over the study period (three years), 2,076 halibut ranging in length from 50 to 207 cm were each tagged with two T-bar anchor tags (also called spaghetti tags). The tags were applied 15 cm apart at the widest point near the dorsal fin on the dark side of the body. Using two tags on each fish enabled us to determine how often tags fall out and are lost, since it is unlikely that both tags would be lost at the same time. Before the pink-tagged halibut were released into the water, the release location, release date, and size of the halibut were recorded.

When tagged halibut are later caught, the tags are returned to the Halibut Assessment Team at BIO. Since each tag is uniquely identified, we are able to determine where and when the halibut was tagged, how far it traveled, the duration it was at large, and how much it grew while carrying the tag. The ability to track halibut movements using these spaghetti tags depends on how much information is provided by the person who caught the fish. Information critical to this project includes location and date caught, fish length and sex, and the fisher's name and contact number. For each halibut's tags and information, the fisher is rewarded with $100, plus a lottery entry for $1,000, drawn four times a year. All entries not drawn remain in the pot for future draws.

By July 2008, 135 of 2,076 tagged halibut had been recaptured. The greatest numbers were caught during times of intensive halibut fishing, such as during surveys and the spring fishery. The tagged fish had moved between 1 km and 2,698 km from their release sites. Notably, two halibut traveled approximately 2,600 km from the Grand Banks to Icelandic waters in about two years. The exact route they traveled cannot be determined using conventional tagging; however, commercial fishing data indicate that most halibut prefer the edge of the continental shelf.

There was no relationship between days at large and distance traveled; however, the dominant movements were to the east and west, with the easterly movements being over greater distances than the westerly movements. The estimated level of exploitation of Atlantic halibut by the commercial fishery was 10.7% in 2006 and 14.9% in

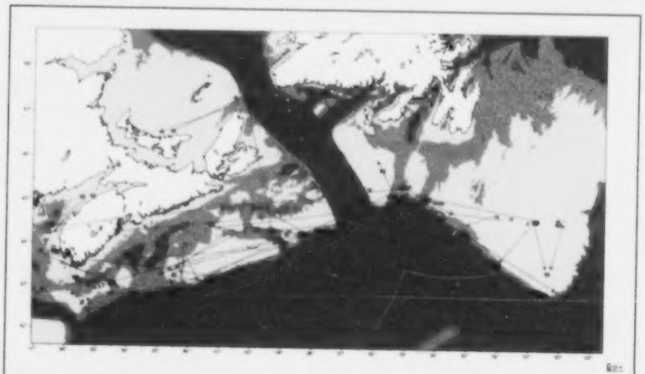
Atlantic halibut with two pink spaghetti tags



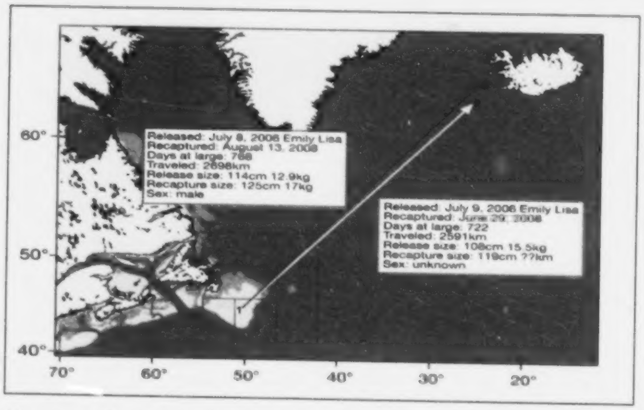
The first tag lottery winner was Frank Reyno. A larger-than-life $1,000 cheque was presented to Donny Hart (on behalf of Mr. Reyno) by George Rennehan, President of the Atlantic Halibut Council (2006-08).

2007, a level which is probably close to optimal exploitation.

Tracking halibut movement using new tagging technologies offers different types of information that can complement information gained from conventional tagging. A pop-up satellite archival tag (PSAT) is an electronic device that can be attached to mobile aquatic species to record depth, temperature, and approximate location for up to 12 months. At a user-specified date and time, the tag activates a corrosion pin on the tag's tether, releasing itself from the halibut and rising to the surface to transmit a data summary to Argo satellites. In June 2007, for the first time in Atlantic Canadian waters, a pop-up satellite archival tag was successfully deployed on a large Atlantic halibut (a 68-kg female).



As of July, 2008, 135 of 2,076 tagged halibut were recaptured between 1 km and 2,698 km from their release sites.



Movement of two spaghetti-tagged Atlantic halibut from the Grand Banks off Newfoundland to near-shore Icelandic waters

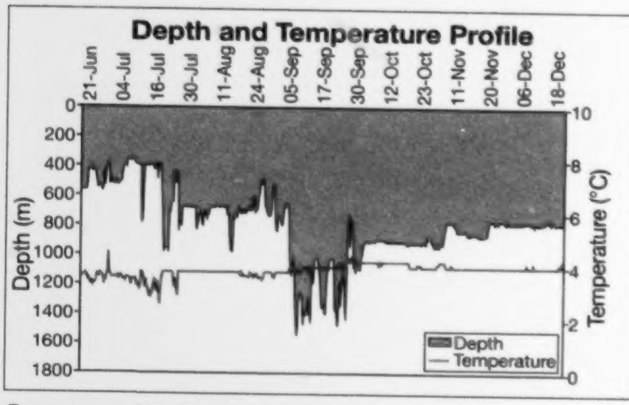
Atlantic halibut with a pop-up archival satellite tag

The large female was caught, tagged, and released on the tail of the Grand Banks. Externally attached to the halibut for just over six months (June to December 2007), the tag was carried approximately 350 km. The PSAT results indicate this halibut preferred a narrow temperature range of between 3 and 5° C, had a depth range of between 400 and 1,500 m, and daily, made rapid ascents and descents in the range of 500 metres. It also appeared this halibut spent extended periods in the water column, possibly feeding.

Results from this single deployment demonstrate the value of conducting future PSAT tagging. In October 2008, the International Governance Strategy Science Program funded a proposal by the Atlantic Halibut Assessment Team to provide up to 12 PSATs to be attached to Atlantic halibut in the Maritimes Region of DFO. These tags are to be deployed from December 2008 to March 2009 and will remain attached to halibut for six to nine months.

Old and new tagging technologies provide different information about distribution, movements, and behaviour of Atlantic halibut. Conventional tagging studies (spaghetti tags) can be cost-effectively deployed in large numbers, which allows the estimation of exploitation rate, an important indicator for optimum management of the halibut fishery. Usually, due to their much higher cost, not enough pop-up satellite tags can be applied to provide this information. Although conventional tagging can show if a halibut moves from its tagging site, it provides no information about the fish's migration route. Also, the return of conventional tags from any given area depends upon someone fishing that area. In contrast, halibut tagged with PSATs do not need to be recaptured, and thus can be used to reconstruct migration pathways, as well as determine net movement, without any bias due to local concentration of fishing effort. Depth and temperature profiles recorded by PSATs can reveal spawning times and locations, and provide estimates of survival after capture

Movement by a PSAT-tagged halibut from June 21, 2007 to December 31, 2007



Temperature and depths profiles from a PSAT-tagged halibut: halibut have a narrow temperature preference (3 to 5° C) and make rapid ascents and descents (~500 m).

and release. Other flatfish species, including Pacific halibut, have been observed to undergo spawning rises, which should be recorded by PSATs if they occur in Atlantic halibut. In addition, the PSATs provide information on vertical and horizontal habitat utilization.

In addition to integrating conventional and PSAT tagging, we plan also to deploy acoustic tags on Atlantic halibut that will be monitored by the Ocean Tracking Network. Integrating results from multiple data sources can improve our understanding of Atlantic halibut biology and ecology, and should improve our ability to optimize fishery catches without jeopardizing conservation.

Ecosystem Interactions with Mussel Aquaculture

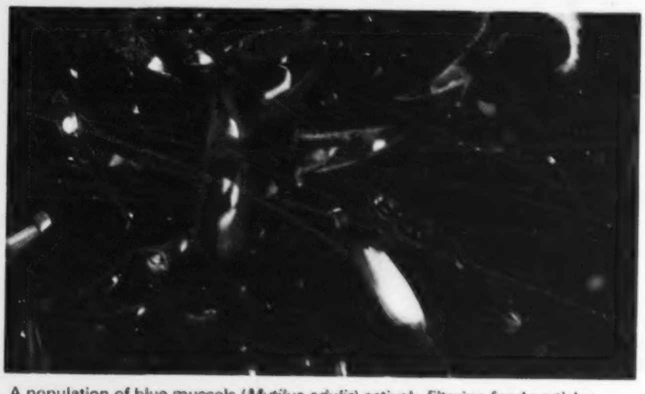
Peter Cranford, Barry Hargrave, and William Li

Aquaculture is the fastest growing food-producing sector in the world and is the only means of filling the growing gap between consumer demand and seafood production from traditional capture fisheries. While there is a need for the continued worldwide expansion of aquaculture to fill this gap, industry development needs to be promoted and managed in a manner that minimizes negative environmental impacts. DFO is committed to ensuring the responsible and environmentally sustainable development of aquaculture and DFO science activities provide advice in support of industry development and regulatory decision making.

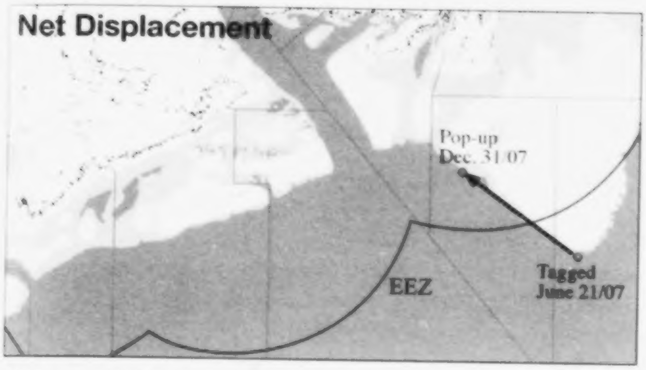
Marine aquaculture activities in Canada encompass a wide array of fish, shellfish, and plant species. Although shellfish aquaculture in Atlantic Canada is a highly diverse industry, mussel culture has developed at an exceptional pace since the 1970s. This rapid growth stems largely from the ease of collecting wild juvenile mussels and the ability of suspended culture methods to achieve a high cultured biomass, per unit area, at relatively low cost.

Unlike finfish culture, which requires the addition of feed and chemical additives, mussel farming relies entirely on natural food supplies. Environmental concerns are related primarily to how the cultured mussels interact within the ecosystem. Mussels have been placed in an exclusive class of animals called "ecosystem engineers" owing to their capacity to create, modify, and maintain habitat. The widely reported changes in the Great Lakes ecosystem that resulted from the invasion of the zebra mussel are a remarkable example of why they have earned this categorization. Mussels live in dense colonies and have an exceptional capacity to filter large volumes of water to extract food (phytoplankton and other suspended particulate matter). While many ecosystem changes may result directly from their considerable role as biofilters, dense populations also excrete large quantities of ammonia and biodeposit undigested organic matter on the seabed. Both activities can have consequences to the structure and functioning of coastal ecosystems.

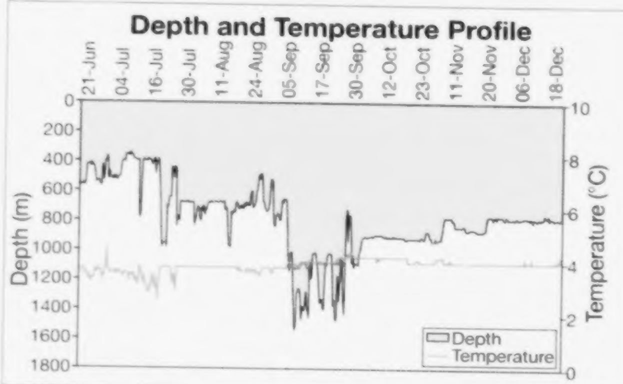
The complexity of possible interactions between mussel culture and the supporting ecosystem creates high potential for unexpected results. Multidisciplinary research is underway through close partnerships between DFO scientists and other leading researchers in Canada, France, Norway, and the Netherlands. This work is designed to improve and integrate knowledge on bay-scale ecological interactions with cultivated bivalves[1] and to aid in the development of effective strategies that will promote the sustainability of the aquaculture industry.



A population of blue mussels (*Mytilus edulis*) actively filtering food particles from the surrounding water – underwater photo courtesy of Øivind Strand



Movement by a PSAT-tagged halibut from June 21, 2007 to December 31, 2007



Temperature and depths profiles from a PSAT-tagged halibut: halibut have a narrow temperature preference (3 to 5° C) and make rapid ascents and descents (~500 m).

and release. Other flatfish species, including Pacific halibut, have been observed to undergo spawning rises, which should be recorded by PSATs if they occur in Atlantic halibut. In addition, the PSATs provide information on vertical and horizontal habitat utilization.

In addition to integrating conventional and PSAT tagging, we plan also to deploy acoustic tags on Atlantic halibut that will be monitored by the Ocean Tracking Network. Integrating results from multiple data sources can improve our understanding of Atlantic halibut biology and ecology, and should improve our ability to optimize fishery catches without jeopardizing conservation.

Ecosystem Interactions with Mussel Aquaculture

Peter Cranford, Barry Hargrave, and William Li

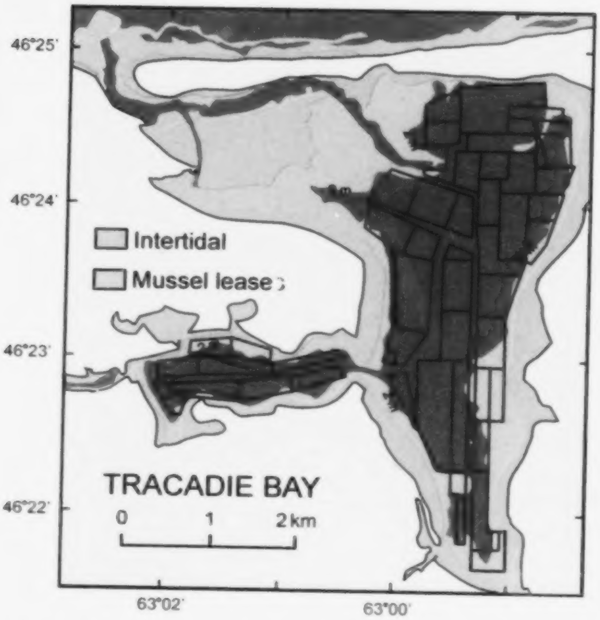
Aquaculture is the fastest growing food-producing sector in the world and is the only means of filling the growing gap between consumer demand and seafood production from traditional capture fisheries. While there is a need for the continued worldwide expansion of aquaculture to fill this gap, industry development needs to be promoted and managed in a manner that minimizes negative environmental impacts. DFO is committed to ensuring the responsible and environmentally sustainable development of aquaculture and DFO science activities provide advice in support of industry development and regulatory decision making.

Marine aquaculture activities in Canada encompass a wide array of fish, shellfish, and plant species. Although shellfish aquaculture in Atlantic Canada is a highly diverse industry, mussel culture has developed at an exceptional pace since the 1970s. This rapid growth stems largely from the ease of collecting wild juvenile mussels and the ability of suspended culture methods to achieve a high cultured biomass, per unit area, at relatively low cost.

Unlike finfish culture, which requires the addition of feed and chemical additives, mussel farming relies entirely on natural food supplies. Environmental concerns are related primarily to how the cultured mussels interact within the ecosystem. Mussels have been placed in an exclusive class of animals called "ecosystem engineers" owing to their capacity to create, modify, and maintain habitat. The widely reported changes in the Great Lakes ecosystem that resulted from the invasion of the zebra mussel are a remarkable example of why they have earned this categorization. Mussels live in dense colonies and have an exceptional capacity to filter large volumes of water to extract food (phytoplankton and other suspended particulate matter). While many ecosystem changes may result directly from their considerable role as biofilters, dense populations also excrete large quantities of ammonia and biodeposit undigested organic matter on the seabed. Both activities can have consequences to the structure and functioning of coastal ecosystems.

The complexity of possible interactions between mussel culture and the supporting ecosystem creates high potential for unexpected results. Multidisciplinary research is underway through close partnerships between DFO scientists and other leading researchers in Canada, France, Norway, and the Netherlands. This work is designed to improve and integrate knowledge on bay-scale ecological interactions with cultivated bivalves[1] and to aid in the development of effective strategies that will promote the sustainability of the aquaculture industry.

A population of blue mussels (*Mytilus edulis*) actively filtering food particles from the surrounding water – underwater photo courtesy of Øivind Strand



Tracadie Bay, Prince Edward Island: the most extensively leased mussel aquaculture site in Canada

Prince Edward Island accounts for the majority of Canadian mussel production and was the focus of an intensive sampling program that included multiple embayments, focusing on Tracadie Bay. Standard mussel aquaculture in Canada first started in Prince Edward Island in the 1970s. Mussel farms (leases), which are used by individuals and companies, expanded over the years to the present state where a large fraction of Tracadie Bay is used for mussel farming. This study investigated the ecological effects of mussel filter-feeding, feces deposition, excretion, and harvesting, as well as interactions between aquaculture and coastal eutrophication[2] from land use.

RECENT FINDINGS

Phytoplankton Depletion

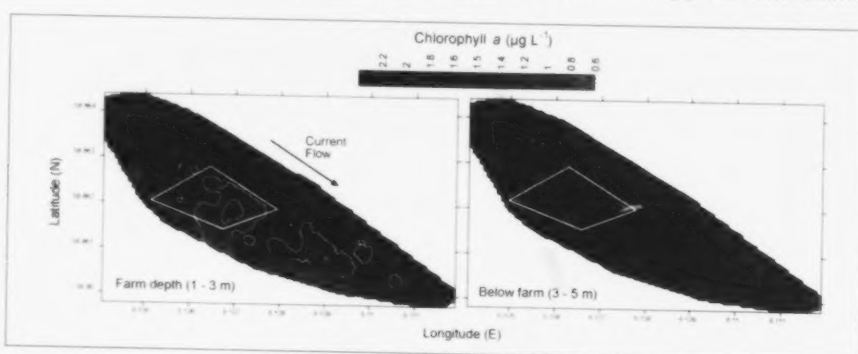
Filter-feeding by mussels naturally results in some local reduction (depletion) of their phytoplankton food supply. However, if the mussel culture is consuming phytoplankton faster than they can be replaced by tidal flushing and phytoplankton growth, then the mussels will become food-limited and mussel production will be less than the maximum for that site. This is referred to as exceeding "production carrying capacity" (see text box). If the spatial scale of phytoplankton depletion expands outward from the farm(s) to include a significant fraction of the coastal inlet, then this effect on the base of the marine food web raises concerns about the ecological costs to other components of the ecosystem. These costs can be used to define the "ecological carrying capacity" of the site.

Detection of the zone of phytoplankton depletion in and around aquaculture sites is not trivial, due to the large degree of natural variation in coastal waters. A new approach was developed at BIO that uses a towed vehicle carrying electronic sensors. The Acrobat tow vehicle is computer controlled to undulate between set water depths while being pulled behind a small boat. The goal of each Acrobat survey is to rapidly collect 3-D (latitude, longitude, and depth) data on phytoplankton concentrations as quickly as possible before the distribution changes with tidal flushing. This rapid, high-resolution, 3-D mapping approach has proven to be reliable for quantifying food depletion at farm to bay-wide scales.

A recent discovery is that intensive mussel culture activities not only affect phytoplankton concentration, but can also alter the size of the plankton at the coastal ecosystem scale. A survey of several PEI embayments in August 2008 found that those bays that are at the highest risk of significant bay-wide particle depletion from mussel culture were dominated by small phytoplankton species that fall within a size class known as picophytoplankton (0.2 – 2.0 micrometers [µm] cell diameter). Picoplankton are able to dominate in these bays because they are too small to be captured by mussels, while their predators (ciliates and flagellates) and major competitors for light and nutrients are removed by the mussels. Although past research indicates that the average picophytoplankton contribution in PEI bays should not exceed about 25% of total phytoplankton biomass, levels between 50% and 80% were observed in several bays, including Tracadie Bay (TR). For aquaculture, this means that food availability for mussel growth might be much lower than is measured using standard water filtration and fluorometric techniques. From the perspective of coastal ecosystems, this result represents a significant destabilization of the basis of the marine food web. A change in phytoplankton size can be expected to alter competition and predator-prey interactions between many resident species.

SPATIAL AND TEMPORAL SCALES OF BENTHIC HABITAT EFFECTS

The effects of increased organic matter biodeposition within mussel farms on benthic habitat were studied in PEI using geochemical indica-



Example maps of the phytoplankton concentration (chlorophyll *a*) around a mussel farm (outlined in yellow) in Norway show food depletion within the depth zone of the farm (left), but not below the farm (right). Contours outlined in white represent the zone exhibiting greater than 20% food depletion. The magnitude and extent of depletion within and outside the farm is related to the region's production and ecological carrying capacity, respectively.

[1] A bivalve is a mollusk with a shell consisting of two valves hinged together.

[2] Eutrophication is a process whereby a body of water receives excess nutrients, resulting in plant overgrowth, then decomposition, and subsequent reduction of oxygen in the water and in the sediment.

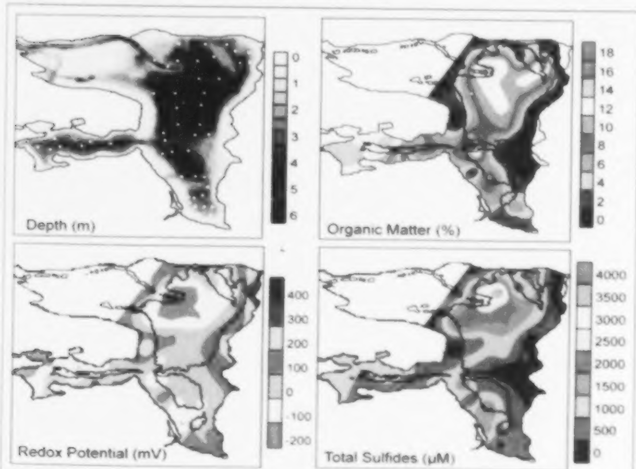
Aquaculture Carrying Capacity

A fundamental difference between the management of wild fisheries and aquaculture is that the former aims to maximize stock removal without impacting the stock or the ecosystem, while the latter strives to maximize the stock addition within a given area without causing similar types of impacts. A goal of aquaculture management is to have tools available that can predict or measure the capacity of an area to support the cultured species. This carrying capacity concept is rapidly evolving from an anthropocentric focus on maximizing aquaculture production to an ecosystem-based management approach that focuses on ecological sustainability. These two concepts are defined as follows:

Production carrying capacity: the maximum sustainable yield of culture that can be produced within a region.

Ecological carrying capacity: the level of culture that can be supported without leading to significant changes to ecological processes, species, populations, or communities in the growing environment.

tors of organic enrichment. Increasing levels of seabed organic enrichment are closely linked to reductions in benthic community diversity. An extensive study of Tracadie Bay showed significantly higher sediment organic enrichment under mussel farms compared to sites located outside farm boundaries, and also provided the first recorded observations of bay-scale benthic effects of shellfish culture. A separate study of 11 coastal embayments in PEI indicated that a 40% increase in mussel production over a four-year period resulted in a doubling of sediment organic enrichment effects under mussel farms. These studies showed that measures of total sulphide and redox[3] potential could be used as general benthic habitat status indicators for differentiating aquaculture sites according to general oxic to anoxic[4] seabed categories. The use of benthic status indicators and site status classifications are important for habitat and aquaculture management initiatives and can be included in the ecosystem-based-management toolbox.



Tracadie Bay survey sites in July, 2003 (upper left) and results from geochemical analysis of seabed samples: sediment organic enrichment, indicated by elevated hypoxic (low oxygen) and sulphidic conditions (the yellow to red areas), occurred near the river mouth on the left of the bay from land-use inputs, and in the deeper central region of the bay from the transport and deposition of detritus and mussel biodeposits. Adapted from Hargrave et al (2008)

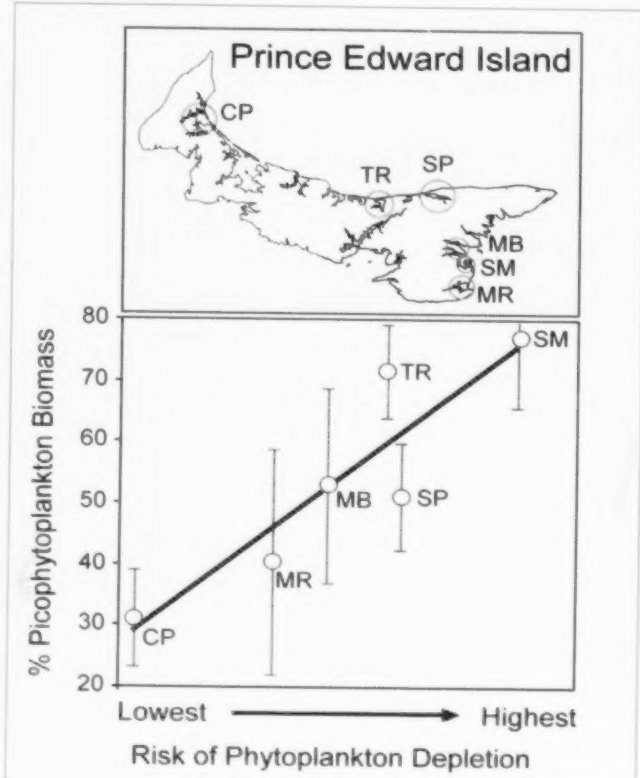
[3] Reduction of oxidation

[4] Oxygen deprived

CONCLUSIONS AND FUTURE RESEARCH

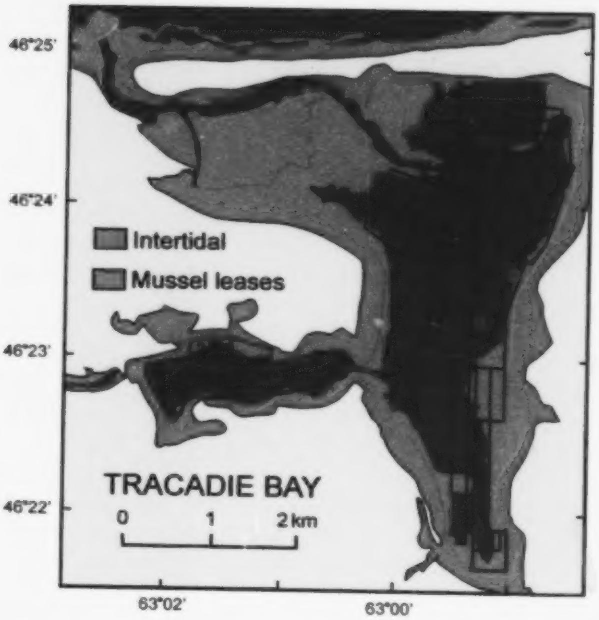
There is a clear need for the continued expansion of sustainable aquaculture production that minimizes negative social and environmental impacts. The results of regulatory science research based on an ecosystem approach help to facilitate the development of impact risk assessment methodologies, the identification of monitoring tools and aquaculture management decision thresholds, the design of farm sampling/monitoring programs, and the identification of appropriate impact mitigation measures. This regulatory science is intended to ensure sustainability and to maintain habitat, biodiversity, and ecosystem productivity.

The extent and magnitude of ecosystem interactions with mussel culture are always site-specific with site vulnerability depending on factors controlling food consumption and waste production (e.g., intensity of mussel production and food concentration) and dispersion. The rate of dispersion determines the capacity of the local environment to prevent excessive food depletion and benthic impacts. Dispersion is controlled by hydrographic and physical factors including current and wind speed, tidal range, and water depth. The relatively high susceptibility to aquaculture effects of the shallow,



Mean contribution of picophytoplankton in six PEI embayments containing different levels of mussel culture (August 18-22, 2008): the percent contribution relative to total phytoplankton biomass is plotted against a phytoplankton depletion risk index that compares bay flushing characteristics with the biofiltering capabilities of the resident mussel farms.

TR = Tracadie Bay
CP = Casumpec Bay
SP = St. Peter's Bay
MB = Montague and Brudenell Rivers
SM = St. Mary's Bay
MR = Murray Harbour



Tracadie Bay, Prince Edward Island: the most extensively leased mussel aquaculture site in Canada

Prince Edward Island accounts for the majority of Canadian mussel production and was the focus of an intensive sampling program that included multiple embayments, focusing on Tracadie Bay. Standard mussel aquaculture in Canada first started in Prince Edward Island in the 1970s. Mussel farms (leases), which are used by individuals and companies, expanded over the years to the present state where a large fraction of Tracadie Bay is used for mussel farming. This study investigated the ecological effects of mussel filter-feeding, feces deposition, excretion, and harvesting, as well as interactions between aquaculture and coastal eutrophication[2] from land use.

RECENT FINDINGS

Phytoplankton Depletion

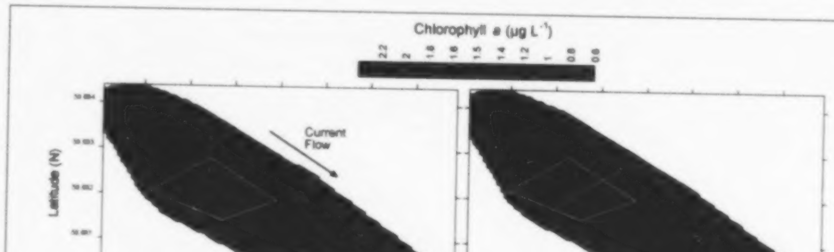
Filter-feeding by mussels naturally results in some local reduction (depletion) of their phytoplankton food supply. However, if the mussel culture is consuming phytoplankton faster than they can be replaced by tidal flushing and phytoplankton growth, then the mussels will become food-limited and mussel production will be less than the maximum for that site. This is referred to as exceeding "production carrying capacity" (see text box). If the spatial scale of phytoplankton depletion expands outward from the farm(s) to include a significant fraction of the coastal inlet, then this effect on the base of the marine food web raises concerns about the ecological costs to other components of the ecosystem. These costs can be used to define the "ecological carrying capacity" of the site.

Detection of the zone of phytoplankton depletion in and around aquaculture sites is not trivial, due to the large degree of natural variation in coastal waters. A new approach was developed at BIO that uses a towed vehicle carrying electronic sensors. The Acrobat tow vehicle is computer controlled to undulate between set water depths while being pulled behind a small boat. The goal of each Acrobat survey is to rapidly collect 3-D (latitude, longitude, and depth) data on phytoplankton concentrations as quickly as possible before the distribution changes with tidal flushing. This rapid, high-resolution, 3-D mapping approach has proven to be reliable for quantifying food depletion at farm to bay-wide scales.

A recent discovery is that intensive mussel culture activities not only affect phytoplankton concentration, but can also alter the size of the plankton at the coastal ecosystem scale. A survey of several PEI embayments in August 2008 found that those bays that are at the highest risk of significant bay-wide particle depletion from mussel culture were dominated by small phytoplankton species that fall within a size class known as picophytoplankton (0.2 – 2.0 micrometers [μm] cell diameter). Picoplankton are able to dominate in these bays because they are too small to be captured by mussels, while their predators (ciliates and flagellates) and major competitors for light and nutrients are removed by the mussels. Although past research indicates that the average picophytoplankton contribution in PEI bays should not exceed about 25% of total phytoplankton biomass, levels between 50% and 80% were observed in several bays, including Tracadie Bay (TR). For aquaculture, this means that food availability for mussel growth might be much lower than is measured using standard water filtration and fluorometric techniques. From the perspective of coastal ecosystems, this result represents a significant destabilization of the basis of the marine food web. A change in phytoplankton size can be expected to alter competition and predator-prey interactions between many resident species.

SPATIAL AND TEMPORAL SCALES OF BENTHIC HABITAT EFFECTS

The effects of increased organic matter biodeposition within mussel farms on benthic habitat were studied in PEI using geochemical indica-



Example maps of the phytoplankton concentration (chlorophyll *a*) around a mussel farm (outlined in yellow) in Norway show food depletion within the depth zone of the farm (left), but not below the farm (right). Contours outlined in white represent the zone exhibiting greater than 20% food depletion. The magnitude and extent of depletion within and outside the farm is related to the region's production and ecological carrying capacity, respectively.

[1] A bivalve is a mollusk with a shell consisting of two valves hinged together.

[2] Eutrophication is a process whereby a body of water receives excess nutrients, resulting in plant overgrowth, then decomposition, and subsequent reduction of oxygen in the water and in the sediment.

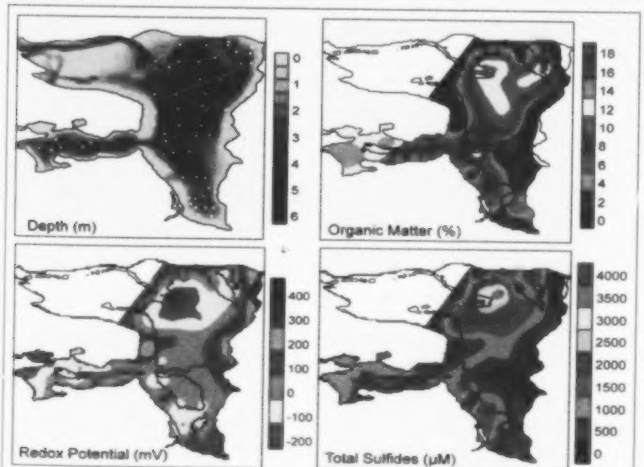
Aquaculture Carrying Capacity

A fundamental difference between the management of wild fisheries and aquaculture is that the former aims to maximize stock removal without impacting the stock or the ecosystem, while the latter strives to maximize the stock addition within a given area without causing similar types of impacts. A goal of aquaculture management is to have tools available that can predict or measure the capacity of an area to support the cultured species. This carrying capacity concept is rapidly evolving from an anthropocentric focus on maximizing aquaculture production to an ecosystem-based management approach that focuses on ecological sustainability. These two concepts are defined as follows:

Production carrying capacity: the maximum sustainable yield of culture that can be produced within a region.

Ecological carrying capacity: the level of culture that can be supported without leading to significant changes to ecological processes, species, populations, or communities in the growing environment.

tors of organic enrichment. Increasing levels of seabed organic enrichment are closely linked to reductions in benthic community diversity. An extensive study of Tracadie Bay showed significantly higher sediment organic enrichment under mussel farms compared to sites located outside farm boundaries, and also provided the first recorded observations of bay-scale benthic effects of shellfish culture. A separate study of 11 coastal embayments in PEI indicated that a 40% increase in mussel production over a four-year period resulted in a doubling of sediment organic enrichment effects under mussel farms. These studies showed that measures of total sulphide and redox[3] potential could be used as general benthic habitat status indicators for differentiating aquaculture sites according to general oxic to anoxic[4] seabed categories. The use of benthic status indicators and site status classifications are important for habitat and aquaculture management initiatives and can be included in the ecosystem-based-management toolbox.



Tracadie Bay survey sites in July, 2003 (upper left) and results from geochemical analysis of seabed samples: sediment organic enrichment, indicated by elevated hypoxic (low oxygen) and sulphidic conditions (the yellow to red areas), occurred near the river mouth on the left of the bay from land-use inputs, and in the deeper central region of the bay from the transport and deposition of detritus and mussel biodeposits. Adapted from Hargrave et al (2008)

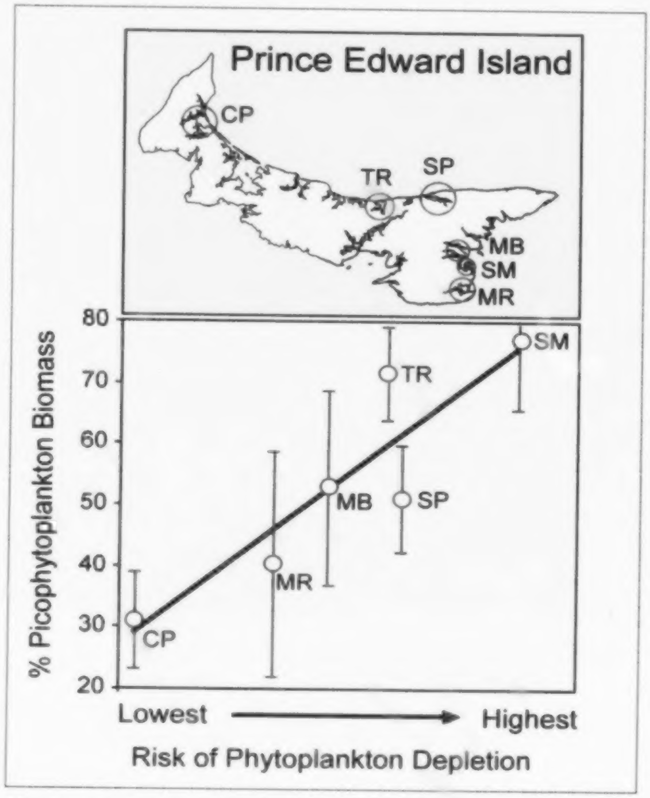
[3] Reduction of oxidation

[4] Oxygen deprived

CONCLUSIONS AND FUTURE RESEARCH

There is a clear need for the continued expansion of sustainable aquaculture production that minimizes negative social and environmental impacts. The results of regulatory science research based on an ecosystem approach help to facilitate the development of impact risk assessment methodologies, the identification of monitoring tools and aquaculture management decision thresholds, the design of farm sampling/monitoring programs, and the identification of appropriate impact mitigation measures. This regulatory science is intended to ensure sustainability and to maintain habitat, biodiversity, and ecosystem productivity.

The extent and magnitude of ecosystem interactions with mussel culture are always site-specific with site vulnerability depending on factors controlling food consumption and waste production (e.g., intensity of mussel production and food concentration) and dispersion. The rate of dispersion determines the capacity of the local environment to prevent excessive food depletion and benthic impacts. Dispersion is controlled by hydrographic and physical factors including current and wind speed, tidal range, and water depth. The relatively high susceptibility to aquaculture effects of the shallow,



Mean contribution of picophytoplankton in six PEI embayments containing different levels of mussel culture (August 18-22, 2008): the percent contribution relative to total phytoplankton biomass is plotted against a phytoplankton depletion risk index that compares bay flushing characteristics with the biofiltering capabilities of the resident mussel farms.

TR = Tracadie Bay
CP = Casumpec Bay
SP = St. Peter's Bay
MB = Montague and Brudenell Rivers
SM = St. Mary's Bay
MR = Murray Harbour

semi-enclosed tidal lagoons and estuaries in PEI results from their low-energy hydrodynamic features, the relatively large areas leased for mussel culture, and considerable nutrient enrichment from land-use.

It is difficult to extrapolate results from one site to another or to make generalizations about the environmental effects of shellfish aquaculture without employing sound ecosystem-based science. DFO scientists are currently working with international colleagues to continue to improve and test methods for predicting and measuring environmental interactions at a wide range of shellfish aquaculture sites, with a focus on providing practical tools for assessing the ecological carrying capacity for shellfish aquaculture.

BIBLIOGRAPHY

Cranford, P.J., P.M. Strain, M. Dowd, J. Grant, B.T. Hargrave, and M-C. Archambault. 2007. Influence of mussel aquaculture on nitrogen dynamics in a nutrient enriched coastal embayment. Mar. Ecol. Prog. Ser. 347:61-78.

Cranford P.J., R. Anderson, P. Archambault, T. Balch, S.S. Bates, G. Bugden, M.D. Callier, C. Carver, L. Comeau, B. Hargrave, W.G. Harrison, E.Horne, P.E. Kepkay, W.K.W. Li, A. Mallet, M. Ouellette, and P. Strain. 2006. Indicators and thresholds for use in assessing shellfish aquaculture impacts on fish habitat, 125 p. DFO Can. Sci. Advis. Sec. Res. Doc. 2006/034. Can Dept. Fisheries and Oceans, Ottawa, ON

Cranford, P.J., B.T. Hargrave, and L.I. Doucette, 2009. Benthic organic enrichment from suspended mussel (*Mytilus edulis*) culture in Prince Edward Island, Canada. Aquaculture. vol. 292, 189-196.

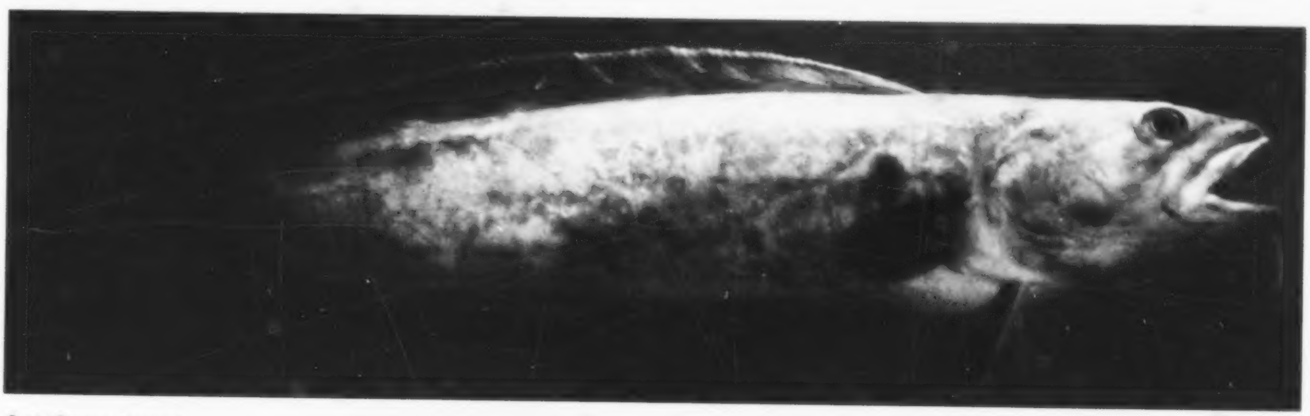
FAO 2008. Food and Agriculture Organization of the United Nations. Aquaculture Newsletter 39. 39 p.
http://www.fao.org/fishery/publications/fan

Grant J., C. Bacher, P.J. Cranford, T. Guyondet, and M. Carreau. 2008. A spatially explicit ecosystem model of seston depletion in dense mussel culture. J. Mar. Syst. vol. 73, 155-168.

Hargrave, B.T., L.I. Doucette, P.J. Cranford, B. A. Law, and T.G. Milligan. 2008. Influence of mussel aquaculture on benthic organic enrichment in a nutrient-rich coastal embayment. Mar. Ecol. Prog. Ser. 365:137-149.

Science Advice on Species at Risk

Tana Worcester



Cusk (*Brosme brosme*)

When cusk, a slow-moving, cod-like fish found along the Atlantic Coast, was first evaluated as threatened by an independent committee of experts in 2003, not many people took notice. However, as the deadline for determining whether it will be listed under the Species at Risk Act draws nearer, fishermen who would be impacted by the restrictive measures this might imply have become concerned. Many fear that closures and catch restrictions will jeopardize their livelihoods, and many disagree with the information used to reach conclusions about its status. Before making a recommendation to the Minister of the Environment, DFO must have a good understanding of the socio-economic implications of listing, as well as the actions and resources required to achieve recovery. DFO Science plays an important role in developing this understanding.

The Maritime Region's Centre for Science Advice (previously known as the Regional Advisory Process or RAP Office) was established by DFO in 1993 to provide peer-reviewed science advice on regional fisheries and oceans issues. Advice historically has focussed on fisheries stock status; however, it has evolved to include human impacts on marine and freshwater species and, more recently, on aquatic species considered to be at risk by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) or listed under the Species at Risk Act (SARA).

In 2004, the Centre for Science Advice started providing advice on species protected under SARA. Assessments were conducted to

determine whether (and how much) human-induced harm to individuals of a protected population could be permitted without jeopardizing its survival or recovery. The first such assessment (called an allowable harm assessment) was conducted for the inner Bay of Fundy salmon. DFO Science advised that any level of harm to this salmon could potentially jeopardize its survival or recovery, and efforts to minimize harm were encouraged. Since then, permits have been issued only for scientific purposes and incidental activities in support of conservation. In the same year, assessments for leatherback turtle and whitefish were conducted as well. These suggested that a low level of harm could be permitted without jeopardizing survival or recovery.

In 2005, the Centre for Science Advice started conducting Recovery Potential Assessments of species that were identified by COSEWIC as threatened or endangered. Rather than advising simply on the levels of allowable harm, these assessments provide a more detailed description of the current status and trajectory of a population, the characteristics and current state of its required habitat, recommended recovery targets, and the likelihood of achieving these targets under current or future conditions. In addition, threats to the population are identified, as are activities or measures that could be used to reduce these threats and enhance survival. The intent is to provide additional information for decision making, including the determination of whether to list new species under SARA, determination of critical habitat for protection, and recovery planning.

Recovery Potential Assessments have been conducted for several sharks (porbeagle, shortfin mako, and white), groundfish (winter skate and cusk), and whales (North Atlantic right and northern bottlenose). North Atlantic right whale and northern bottlenose whale were already listed as endangered under SARA when their assessments were conducted, so advice was primarily intended to identify recovery targets and support recovery planning, including the identification of critical habitat. Assessments for sharks and groundfish in the Maritimes Region have not resulted in the protection of any new species under SARA; however, efforts have been made to reduce mortality on these species where possible. For example, fishery catch limits have been reduced for porbeagle shark. In 2008, a Recovery Potential Assessment was conducted also for the inner Bay of Fundy salmon. It was suggested that this salmon is unlikely to survive or recover without ongoing human intervention under current conditions. Additional protective measures are being considered, including the identification (leading to protection) of critical habitat.

The Maritimes Centre for Science Advice held its first pre-COSEWIC assessment in 2007. This type of assessment gathers and reviews all the scientific information available from DFO on a species or population that is about to be evaluated by COSEWIC. The results of this analysis are provided to the Committee to assist in its determination of species status. The assessment also helps DFO to identify further work that needs to be done to support recovery planning should that species be identified as threatened or endangered. Early identification of knowledge gaps is particularly important for non-commercial species and other species on which DFO may have limited information. New data may have to be collected or new analytical tools developed before an adequate Recovery Potential Assessment can be conducted.

In 2007 and 2008, pre-COSEWIC assessments were conducted for spiny dogfish, basking shark, barndoor skate, and Atlantic cod. It is too early to determine how this information will be used by COSEWIC in its deliberations; however, these assessments helped ensure that the most up-to-date and appropriate information from DFO was available for consideration.

Inner Bay of Fundy salmon (*Salmo salar*)

Barndoor Skate (*Dipturus laevis*)

Since the enactment of SARA in June 2003, DFO Maritimes' Centre for Science Advice has coordinated fourteen assessments of thirteen species, representing the culmination of thousands of hours of data collection, synthesis, analysis, review, and reporting. As the number of species to be evaluated and re-evaluated by COSEWIC, and potentially listed under SARA, continues to increase, so, too, do the responsibilities and workload for DFO Science. While the information and recommendations provided by the Centre for Science Advice have supported the implementation of numerous measures put in place to protect species at risk, it remains to be seen what impact science advice ultimately has on the survival and recovery of these species.

Whether or not cusk is listed under the Species at Risk Act, there have already been changes in the way we think about and manage our interactions with this species. By focusing inquisitive minds on its plight, the fate of cusk may have already changed for the better.

The North Atlantic Right Whale — A Recovery Strategy for One of the World's Most Endangered Cetaceans

Koren Spence

The North Atlantic right whale is a large migratory baleen whale that was driven to near extinction by whaling in the 1800s. Despite the end of commercial whaling in the 1930s, right whale numbers have failed to rebound and current population estimates are around 400 individuals, many of which spend part of the year in Canadian waters, primarily in the lower Bay of Fundy and the Roseway Basin on the southwestern Scotian Shelf. For over a decade these whales have been the subject of research and recovery efforts undertaken by DFO and other organizations including industry, universities, international groups, other government departments, and environmental groups. Much of DFO's work has been carried out by staff at BIO and St. Andrews Biological Station (SABS) in New Brunswick. This work has contributed to the development of a draft North Atlantic Right Whale Recovery Strategy and published on the Species At Risk Public Registry in 2009.

WHAT IS A RECOVERY STRATEGY?

A Recovery Strategy is a planning document that sets goals and objectives for recovery, identifies knowledge gaps, and outlines efforts to be undertaken to reverse a species decline. It is a precursor to an Action Plan, which guides the implementation of the Recovery Strategy. *The Species at Risk Act* (SARA) was passed in 2003 *"to provide for the recovery of wildlife species that are extirpated, endangered or threatened as a result of human activity and to manage species of special concern to prevent them from becoming endangered or threatened."* It is an offence to *"kill, harm, harass, capture, take, possess, collect, buy, sell or trade"* any species listed as extirpated, endangered, or threatened under the Act, and the Federal Government is responsible for developing and implementing a Recovery Strategy for these species. North Atlantic right whales were listed as endangered when the SARA came into effect, and as

North Atlantic right whale, surfacing in the Bay of Fundy – photo courtesy of Kent Smedbol, SABS

such, a SARA-compliant Recovery Strategy was developed with input from the Right Whale Recovery Team, under the lead of staff at BIO and St. Andrew's Biological Station (SABS).

THE BIOLOGY, THREATS, AND HABITAT OF THE NORTH ATLANTIC RIGHT WHALE

The North Atlantic right whale is a black baleen whale that can reach 17 metres in length. Its distinguishing characteristics include its lack of a dorsal fin and the presence of large, white, roughened patches of skin, called callosities, on its head. These callosities form patterns which are unique to each whale, and are used by researchers to identify individuals.

The major threats to North Atlantic right whales are collisions with vessels and entanglement in fixed fishing gear. Habitat degradation (including contaminants and increases in underwater noise) and changes in the food supply may also be contributing to the species' failure to recover more rapidly. Recovery has also been limited by the whales' low reproductive rates and low levels of genetic diversity.

Many of the 400 remaining North Atlantic right whales spend

Map shows the North American range of the North Atlantic right whale.

the summer and fall off the coast of Nova Scotia. They are often seen feeding and socializing in areas with large populations of their prey (zooplankton), including in the Grand Manan and Roseway basins. Grand Manan Basin has been recognized as a particularly important location for right whales and in some years as many as two-thirds of the known population have been seen in this region. Grand Manan and Roseway basins were designated Conservation Areas in 1993 and areas within the basins have been identified as Critical Habitat in the recovery strategy. SARA defines Critical Habitat as "*the habitat that is necessary for the survival or recovery of a listed wildlife species*" and identified aquatic Critical Habitat is protected from destruction under the Act.

RECOVERY OBJECTIVES FOR NORTH ATLANTIC RIGHT WHALES

Several recovery objectives have been identified in the Recovery Strategy as activities necessary to achieve the goal of establishing an increasing trend in right whale abundance over three generations. Guidance as to how to implement and achieve these objectives will be detailed in the Action Plan. The identified objectives include:

1. reduction of death and injury from vessel strikes;
2. reduction of death and injury from fishing gear entanglement;
3. reduction of injury and disturbance from vessel noise, exposure to contaminants, and other forms of habitat degradation;
4. monitoring populations and threats;
5. conducting research to increase our understanding of right whale biology, habitat, and threats to recovery;
6. supporting and promoting collaboration among government agencies, researchers, environmental groups, Aboriginal groups, coastal communities, and international agencies; and
7. developing and implementing education and stewardship activities.

PAST SUCCESSES

Right whale recovery efforts have been driven by non-government organizations, DFO staff, industry, and other government departments. Past successes include the 2003 relocation of the shipping lanes in the Bay of Fundy, led by Transport Canada and estimated to have reduced potential vessel/whale collisions by 80%; the designation of Roseway Basin as a seasonal Area to Be Avoided for large vessels; and a collaborative effort among DFO, fishing associations, and environmental groups which led to the development of a proactive mitigation strategy to reduce right whale interactions with lobster fishing gear.

You can obtain more information on recovery efforts for right whales by contacting the Maritimes Region SARA Coordination Office at xmarsara@mar.dfo-mpo.gc.ca or 1-866-891-0771.

A pod of right whales – photo courtesy of Moira Brown, New England Aquarium

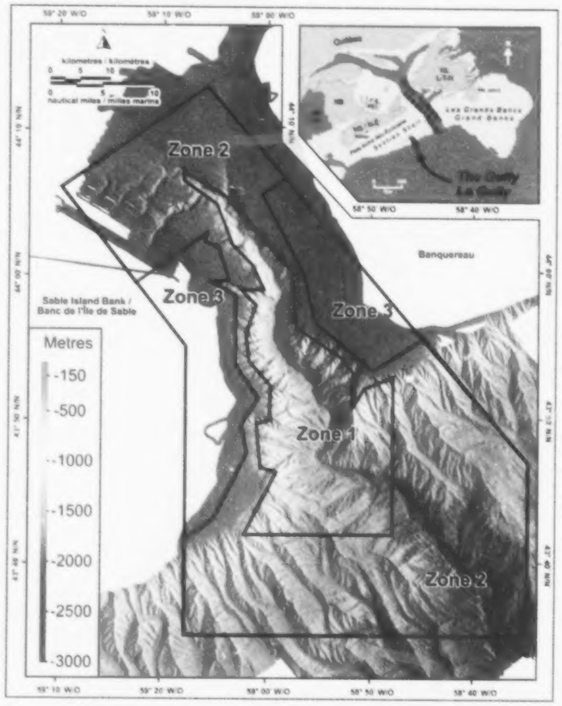
Conserving the Health, Integrity, and Productivity of our Marine Ecosystems: An Update on Marine Protected Areas in the Maritimes Region

Kristian Curran, Tracy Horsman, and Paul Macnab*

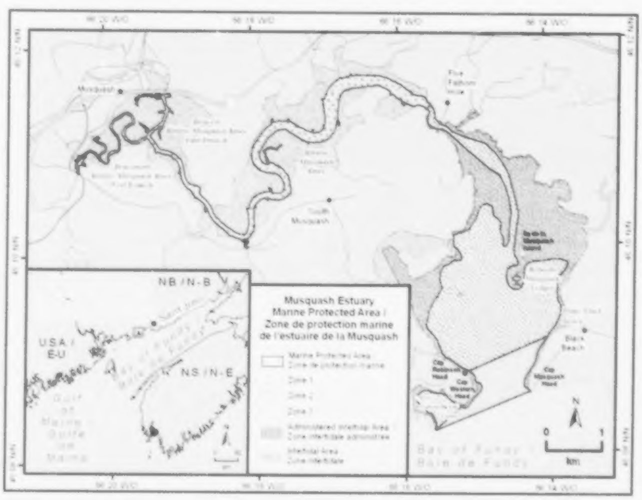
A Marine Protected Area (MPA) is a coastal or marine area given special status to conserve and protect its natural habitat and wildlife. MPAs are designated under Canada's *Oceans Act* (1997), and are managed by DFO on behalf of all Canadians. In the Maritimes Region, two MPAs exist: The Gully MPA offshore Nova Scotia, designated May 7, 2004 and the Musquash Estuary MPA in coastal southwest New Brunswick (NB), designated December 14, 2006. The Oceans and Coastal Management Division (OCMD) within the Oceans, Habitat and Species at Risk Branch at DFO is responsible for managing these two MPAs. This article by staff of the OCMD provides an update on The Gully MPA and Musquash Estuary MPA, as well as an update on the identification of future MPAs within the region.

During the Spring of 2008 The Gully MPA entered its fifth year of providing statutory protection to the largest submarine canyon in eastern North America. The OCMD continues to work across DFO sectors, in collaboration with several groups at BIO and with many others in the oceans community, to study, safeguard, manage, and communicate about the MPA. The Gully Management Plan was developed and released this year with the assistance of The Gully Advisory Committee, a multi-stakeholder body established to advise DFO on Gully-related matters. The plan lays out conservation objectives and priorities for the MPA, while providing guidance to regulators, user groups, and the general public. It also highlights required management actions, many of which are underway, including the development and implementation of research and monitoring plans. Managing a wholly offshore site is not without challenges but, thankfully, many of the science, surveillance, and communication needs have been met and exceeded by colleagues within DFO, and by other government, non-government, academic, and industry partners in marine conservation. For example, a particular advantage for the MPA management team is its location at BIO, amidst a large multidisciplinary community with significant strengths in marine science and technology. Fortunately for The Gully MPA, many priority themes for management, like seabed mapping, ecosystem studies, data integration and visualization, and contaminant assessment are well aligned with areas of expertise and interest housed within the Institute.

It has been two years since Musquash Estuary in southwest NB was designated an MPA. In that time, the OCMD has worked with various DFO sectors, other federal regulators, and the Government of New Brunswick to ensure that this unique ecosystem is protected. The OCMD has been working also with many stakeholders on a draft management plan for the estuary, which is anticipated to receive formal support in the spring of 2009. Drafting the management plan has posed an interesting challenge. In Musquash Estuary, DFO is responsible for managing activities within the permanently



The Gully MPA located offshore Nova Scotia – figure courtesy of Stan Johnston



Musquash Estuary MPA located in southwest New Brunswick – figure courtesy of Stan Johnston

Map shows the North American range of the North Atlantic right whale.

the summer and fall off the coast of Nova Scotia. They are often seen feeding and socializing in areas with large populations of their prey (zooplankton), including in the Grand Manan and Roseway basins. Grand Manan Basin has been recognized as a particularly important location for right whales and in some years as many as two-thirds of the known population have been seen in this region. Grand Manan and Roseway basins were designated Conservation Areas in 1993 and areas within the basins have been identified as Critical Habitat in the recovery strategy. SARA defines Critical Habitat as "*the habitat that is necessary for the survival or recovery of a listed wildlife species*" and identified aquatic Critical Habitat is protected from destruction under the Act.

RECOVERY OBJECTIVES FOR NORTH ATLANTIC RIGHT WHALES

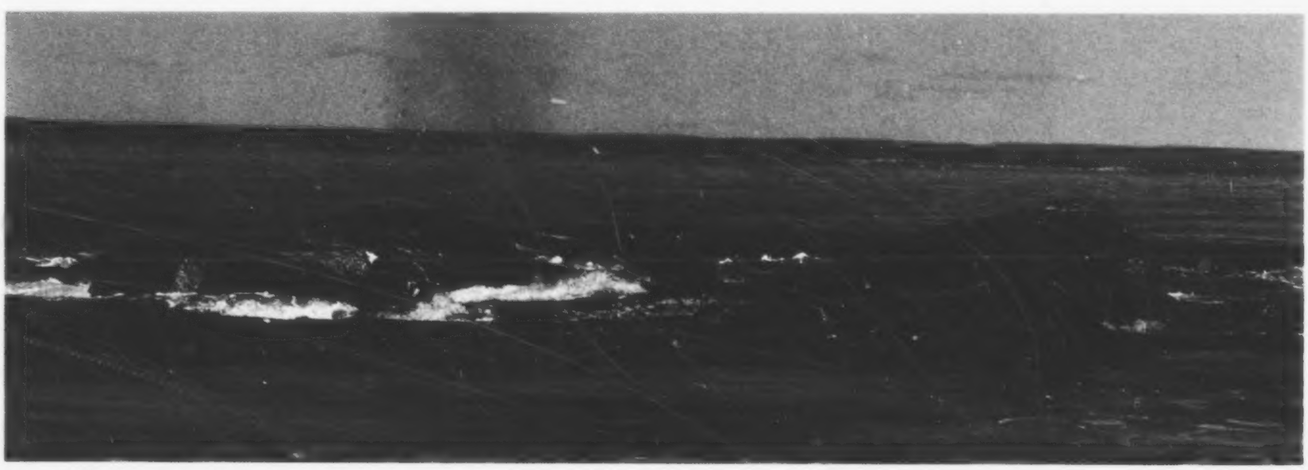
Several recovery objectives have been identified in the Recovery Strategy as activities necessary to achieve the goal of establishing an increasing trend in right whale abundance over three generations. Guidance as to how to implement and achieve these objectives will be detailed in the Action Plan. The identified objectives include:

1. reduction of death and injury from vessel strikes;
2. reduction of death and injury from fishing gear entanglement;
3. reduction of injury and disturbance from vessel noise, exposure to contaminants, and other forms of habitat degradation;
4. monitoring populations and threats;
5. conducting research to increase our understanding of right whale biology, habitat, and threats to recovery;
6. supporting and promoting collaboration among government agencies, researchers, environmental groups, Aboriginal groups, coastal communities, and international agencies; and
7. developing and implementing education and stewardship activities.

PAST SUCCESSES

Right whale recovery efforts have been driven by non-government organizations, DFO staff, industry, and other government departments. Past successes include the 2003 relocation of the shipping lanes in the Bay of Fundy, led by Transport Canada and estimated to have reduced potential vessel/whale collisions by 80%; the designation of Roseway Basin as a seasonal Area to Be Avoided for large vessels; and a collaborative effort among DFO, fishing associations, and environmental groups which led to the development of a proactive mitigation strategy to reduce right whale interactions with lobster fishing gear.

You can obtain more information on recovery efforts for right whales by contacting the Maritimes Region SARA Coordination Office at xmarsara@mar.dfo-mpo.gc.ca or 1-866-891-0771.



A pod of right whales – photo courtesy of Moira Brown, New England Aquarium

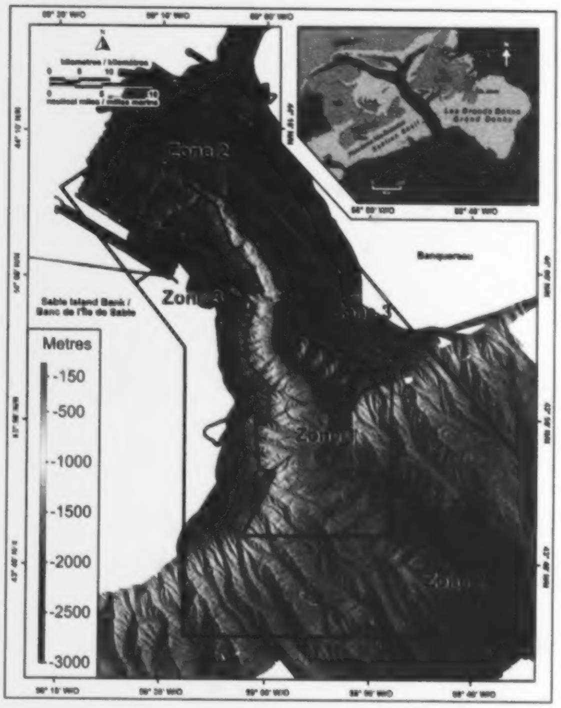
Conserving the Health, Integrity, and Productivity of our Marine Ecosystems: An Update on Marine Protected Areas in the Maritimes Region

Kristian Curran, Tracy Horsman, and Paul Macnab*

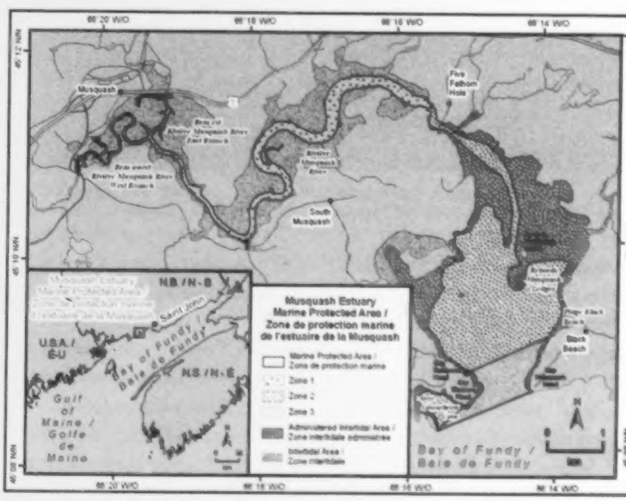
A Marine Protected Area (MPA) is a coastal or marine area given special status to conserve and protect its natural habitat and wildlife. MPAs are designated under Canada's *Oceans Act* (1997), and are managed by DFO on behalf of all Canadians. In the Maritimes Region, two MPAs exist: The Gully MPA offshore Nova Scotia, designated May 7, 2004 and the Musquash Estuary MPA in coastal southwest New Brunswick (NB), designated December 14, 2006. The Oceans and Coastal Management Division (OCMD) within the Oceans, Habitat and Species at Risk Branch at DFO is responsible for managing these two MPAs. This article by staff of the OCMD provides an update on The Gully MPA and Musquash Estuary MPA, as well as an update on the identification of future MPAs within the region.

During the Spring of 2008 The Gully MPA entered its fifth year of providing statutory protection to the largest submarine canyon in eastern North America. The OCMD continues to work across DFO sectors, in collaboration with several groups at BIO and with many others in the oceans community, to study, safeguard, manage, and communicate about the MPA. The Gully Management Plan was developed and released this year with the assistance of The Gully Advisory Committee, a multi-stakeholder body established to advise DFO on Gully-related matters. The plan lays out conservation objectives and priorities for the MPA, while providing guidance to regulators, user groups, and the general public. It also highlights required management actions, many of which are underway, including the development and implementation of research and monitoring plans. Managing a wholly offshore site is not without challenges but, thankfully, many of the science, surveillance, and communication needs have been met and exceeded by colleagues within DFO, and by other government, non-government, academic, and industry partners in marine conservation. For example, a particular advantage for the MPA management team is its location at BIO, amidst a large multidisciplinary community with significant strengths in marine science and technology. Fortunately for The Gully MPA, many priority themes for management, like seabed mapping, ecosystem studies, data integration and visualization, and contaminant assessment are well aligned with areas of expertise and interest housed within the Institute.

It has been two years since Musquash Estuary in southwest NB was designated an MPA. In that time, the OCMD has worked with various DFO sectors, other federal regulators, and the Government of New Brunswick to ensure that this unique ecosystem is protected. The OCMD has been working also with many stakeholders on a draft management plan for the estuary, which is anticipated to receive formal support in the spring of 2009. Drafting the management plan has posed an interesting challenge. In Musquash Estuary, DFO is responsible for managing activities within the permanently



The Gully MPA located offshore Nova Scotia – figure courtesy of Stan Johnston



Musquash Estuary MPA located in southwest New Brunswick – figure courtesy of Stan Johnston

This ocean pout (*Zoarces americanus*) was observed by DFO scientists during a benthic survey in and around a morraine in Zone 3 (east) of The Gully MPA. The image was collected using Campod, a video system designed at BIO to observe the seafloor and its marine life, during the *Hudson* 2008-015 mission.

A tidal channel meanders through the salt marsh ecosystem that surrounds the upper Musquash Estuary MPA. Photo courtesy of David Thompson (Conservation Council of New Brunswick)

wet areas pursuant to the MPA Regulations, but is also responsible for managing activities in certain intertidal areas throughout the estuary. The DFO-administered intertidal areas, however, do not fall under the jurisdiction of the *Oceans Act* and, as a result, the Musquash Estuary MPA Regulations cannot be used to conserve and protect them. The Government of Canada committed to the Government of New Brunswick to manage the administered intertidal areas in a manner similar to the MPA. To uphold this commitment, the OCMD, in co-ordination with DFO's Habitat Protection and Sustainable Development Division and the Fisheries and Aquaculture Management Branch, is managing the administered intertidal areas under the *Fisheries Act*. The aim is to manage activities in these areas in a manner that is consistent with the management of activities in the MPA. In support of management, staff at St. Andrews Biological Station (SABS) in NB, Canada's first marine biological research station and a proud part of DFO, continue to provide a scientific basis for understanding the effects of human activities within the estuary. The DFO Conservation and Protection Branch oversees marine enforcement within the estuary.

The *Oceans Act* and supporting documents such as the federal Marine Protected Areas Strategy (2005) describe the need for a system or network of marine protected areas in Canada. Fulfilling this vision is a key activity for DFO staff, and several initiatives are underway to identify a suite of marine sites in the Maritimes Region that may require protection as an MPA. Linkages are also being made to the objectives of DFO's overall integrated ocean management efforts within the region. As a key step to meeting the MPA network vision, DFO announced in October 2007 the intent to identify and designate six new MPAs under the national Health of the Oceans initiative, which include one or more sites within the Maritimes Region. To make progress on network design and the selection of future sites, a regional Oceans and Science Branch MPA Working Group has been established. This group has drawn on the wealth of knowledge at BIO and SABS, and from non-government, academic, and industry partners to assemble the relevant ecological information for MPA planning. This includes understanding the distribution of significant and depleted marine species, biodiversity hotspots, habitat sensitivities, and seabed classification. For most of the offshore areas, this ecological information is being analyzed using GIS-based Marxan software, a protected areas decision-support tool designed at the University of Queensland, which has been used worldwide to assist scientists and managers in MPA selection.

Management of The Gully and Musquash Estuary MPAs continues to be a learning experience for MPA practitioners within the OCMD. The knowledge and experience that have been gained over the past five years will contribute to the designation and management of future MPAs in Maritimes Region. Management of The Gully and Musquash Estuary MPAs, as well as the identification of potential future sites, are great examples of cooperation occurring among DFO sectors within our region.

*Contact - Kristian Curran, (902) 426-6392; Kristian.Curran@dfo-mpo.gc.ca

Partnerships Making a Difference: The River Denys Watershed

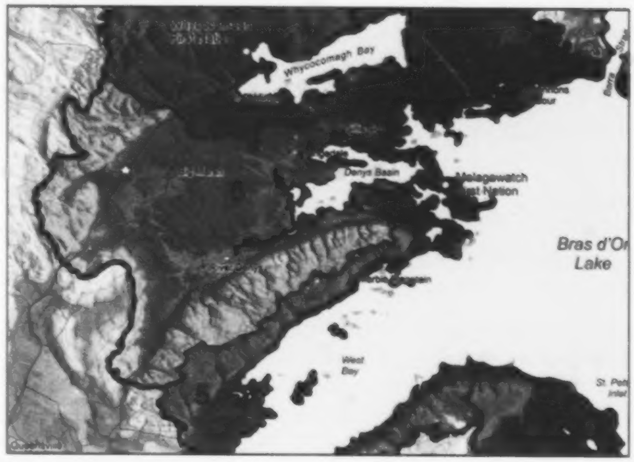
Darren Hiltz and Jason Naug

The River Denys watershed is one of the twelve sub-watershed management units of the Bras d'Or Lakes, a semi-enclosed inland sea on Cape Breton Island, Nova Scotia. The watershed is approximately 300 km^2 in area and contains the River Denys, one of four major rivers flowing into the Bras d'Or Lakes. Important ecological features in this watershed include both marine and terrestrial features such as Bald Eagle nesting sites; the Bornish Hills Nature Reserve; salmon, trout, and herring spawning areas; a significant wetland complex; a large deer wintering area; a provincially vulnerable Wood Turtle population; and an oyster fishery once of regional significance. The River Denys watershed has long supported various human activities, such as gypsum mining, agriculture, cottage development, forestry, fishing, marble mining, a landfill, oyster fishing, and aquaculture. It is currently experiencing the effects from many of these.

Since 1999, a non-profit community group, the Stewards of the River Denys Basin Watershed Association, has been concerned with the maintenance, protection, and restoration of this unique environment. The association has fostered many important partnerships toward this end, with First Nations, industry, non-government organizations, other government departments, and DFO. Each of these partners has played an important role in trying to better manage this area. The Eskasoni Fish and Wildlife Commission has raised awareness and interest in the issues associated with the River Denys area and supported this work. Georgia-Pacific (GP), a multi-national company headquartered in Atlanta, Georgia, with one active and one inactive gypsum mine in the watershed, has been providing in-kind and financial support. The Nova Scotia Salmon Association has provided funds and expertise to the many restoration efforts that have taken place, and DFO has assisted the Stewards in the development of a sub-watershed management plan and has coordinated habitat restoration activities to help implement it. DFO has also undertaken scientific programs in the area under the Science for the Integrated Management of the Bras d'Or Lakes program.

Addressing the various issues raised by the community group in this watershed was thought to be best achieved through the development of a sub-watershed management plan, where specific priorities can be identified, organizations and people engaged, and efforts coordinated. The Oceans and Coastal Management Division of DFO has helped facilitate the development of this plan on behalf of the Stewards and the community. The management plan has in part been based on a review of the existing information and the opinions of residents gained through a survey of 350 households, interviews, and public meetings.

The management approach in the River Denys sub-watershed is linked to that for the entire Bras d'Or Lakes, through a broader intergovernmental, First Nations, industry, NGO, and community planning body called the Collaborative Environmental Planning Initiative (CEPI). CEPI is pursuing an overall plan for the entire Bras d'Or Lakes area and watershed and envisions sub-watershed plans as part of this approach. In contrast to an overall plan which is more strategic in nature, sub-watershed plans are site-specific, support a greater involvement of residents, and allow for the development of manageable-sized local projects.



The River Denys sub-watershed

To date, a number of projects have been undertaken to implement the River Denys plan and its top priorities including improving fish habitat, public education on environmental issues, assessing impacts from a former landfill site, addressing the illegal dumping of garbage, and restoring oyster populations in the basin. Primary among the actions has been a series of important habitat restoration projects coordinated by DFO's Habitat Protection & Sustainable Development Division (HPSDD).

In 2000, members of the Stewards of River Denys Watershed Association and the NSSA, led by the HPSDD, conducted a habitat assessment on McIntyre Brook. Over a three-year period, the Stewards conducted in-stream restoration projects including the installation of various in-stream fish habitat enhancement structures used to enhance pool, riffle, spawning, and nursery habitats. In 2002, the Stewards began efforts in Big Brook at the location of a former gypsum mine owned by GP. This was the beginning of a unique partnership between industry and community. The HPSDD worked in partnership with the Stewards, Eskasoni Fish and Wildlife Commission, and GP to conduct habitat assessments. The completed restoration activities included: culvert removals to improve fish migration, bank stabilization, and bioengineering; installation of 37 in-stream fish habitat enhancement structures; and volunteer monitoring of fish populations and water quality to assess the potential impact of the local landfill.

Ongoing work within this sub-watershed includes the development of a habitat assessment and restoration plan for the Glen Brook which flows adjacent to the active gypsum mine that GP owns. In 2008, members of a project team including GP, DFO, Adopt-a-Stream, First Nations Guardians, the Stewards, and consultants conducted habitat assessments so that restoration plans and priori-

Partnerships Making a Difference: The River Denys Watershed

Darren Hiltz and Jason Naug

The River Denys watershed is one of the twelve sub-watershed management units of the Bras d'Or Lakes, a semi-enclosed inland sea on Cape Breton Island, Nova Scotia. The watershed is approximately 300 km² in area and contains the River Denys, one of four major rivers flowing into the Bras d'Or Lakes. Important ecological features in this watershed include both marine and terrestrial features such as Bald Eagle nesting sites; the Bornish Hills Nature Reserve; salmon, trout, and herring spawning areas; a significant wetland complex; a large deer wintering area; a provincially vulnerable Wood Turtle population; and an oyster fishery once of regional significance. The River Denys watershed has long supported various human activities, such as gypsum mining, agriculture, cottage development, forestry, fishing, marble mining, a landfill, oyster fishing, and aquaculture. It is currently experiencing the effects from many of these.

The River Denys sub-watershed

Since 1999, a non-profit community group, the Stewards of the River Denys Basin Watershed Association, has been concerned with the maintenance, protection, and restoration of this unique environment. The association has fostered many important partnerships toward this end, with First Nations, industry, non-government organizations, other government departments, and DFO. Each of these partners has played an important role in trying to better manage this area. The Eskasoni Fish and Wildlife Commission has raised awareness and interest in the issues associated with the River Denys area and supported this work. Georgia-Pacific (GP), a multi-national company headquartered in Atlanta, Georgia, with one active and one inactive gypsum mine in the watershed, has been providing in-kind and financial support. The Nova Scotia Salmon Association has provided funds and expertise to the many restoration efforts that have taken place, and DFO has assisted the Stewards in the development of a sub-watershed management plan and has coordinated habitat restoration activities to help implement it. DFO has also undertaken scientific programs in the area under the Science for the Integrated Management of the Bras d'Or Lakes program.

Addressing the various issues raised by the community group in this watershed was thought to be best achieved through the development of a sub-watershed management plan, where specific priorities can be identified, organizations and people engaged, and efforts coordinated. The Oceans and Coastal Management Division of DFO has helped facilitate the development of this plan on behalf of the Stewards and the community. The management plan has in part been based on a review of the existing information and the opinions of residents gained through a survey of 350 households, interviews, and public meetings.

The management approach in the River Denys sub-watershed is linked to that for the entire Bras d'Or Lakes, through a broader intergovernmental, First Nations, industry, NGO, and community planning body called the Collaborative Environmental Planning Initiative (CEPI). CEPI is pursuing an overall plan for the entire Bras d'Or Lakes area and watershed and envisions sub-watershed plans as part of this approach. In contrast to an overall plan which is more strategic in nature, sub-watershed plans are site-specific, support a greater involvement of residents, and allow for the development of manageable-sized local projects.

To date, a number of projects have been undertaken to implement the River Denys plan and its top priorities including improving fish habitat, public education on environmental issues, assessing impacts from a former landfill site, addressing the illegal dumping of garbage, and restoring oyster populations in the basin. Primary among the actions has been a series of important habitat restoration projects coordinated by DFO's Habitat Protection & Sustainable Development Division (HPSDD).

In 2000, members of the Stewards of River Denys Watershed Association and the NSSA, led by the HPSDD, conducted a habitat assessment on McIntyre Brook. Over a three-year period, the Stewards conducted in-stream restoration projects including the installation of various in-stream fish habitat enhancement structures used to enhance pool, riffle, spawning, and nursery habitats. In 2002, the Stewards began efforts in Big Brook at the location of a former gypsum mine owned by GP. This was the beginning of a unique partnership between industry and community. The HPSDD worked in partnership with the Stewards, Eskasoni Fish and Wildlife Commission, and GP to conduct habitat assessments. The completed restoration activities included: culvert removals to improve fish migration, bank stabilization, and bioengineering; installation of 37 in-stream fish habitat enhancement structures; and volunteer monitoring of fish populations and water quality to assess the potential impact of the local landfill.

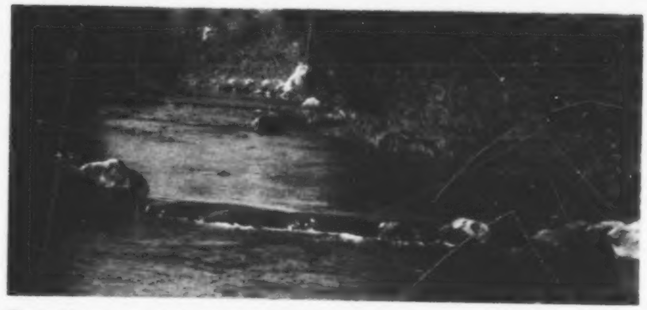
Ongoing work within this sub-watershed includes the development of a habitat assessment and restoration plan for the Glen Brook which flows adjacent to the active gypsum mine that GP owns. In 2008, members of a project team including GP, DFO, Adopt-a-Stream, First Nations Guardians, the Stewards, and consultants conducted habitat assessments so that restoration plans and priori-

DENYS BASIN MANAGEMENT PLAN IMPLEMENTATION: GLEN BROOK HABITAT ASSESSMENT

Planning the day's work are, from left: Robert Livingstone (Stewards of the River Denys Watershed Association), Keith Christmas (Membertou Guardians), Gerrard McMaster (Georgia-Pacific), Jim Foulds (Eco-boy Consulting), George Christmas (Chapel Island Guardians), Blair Bernard (Unama'ki Institute of Natural Resources), and Amy Weston (Nova Scotia Salmon Association). Missing from the photo is Darren Hiltz, DFO.

ties can be developed and implemented in the future. This included a training opportunity to help educate those user groups in this area. In addition, the Unama'ki Institute of Natural Resources (UINR), the Stewards, and the Nova Scotia Department of Transportation and Infrastructure Renewal (NSDIR) have worked in partnership on

DENYS BASIN MANAGEMENT PLAN IMPLEMENTATION: BIG BROOK HABITAT ENHANCEMENT



Typical in-stream habitat enhancement structures located in Big Brook

a multi-year project to improve and monitor oyster habitat in Denys Basin. This project is funded by the NSDIR through DFO's Habitat Compensation requirements and will help address a priority identified in the management plan.

The work in the River Denys sub-watershed serves as a model for how similar areas can be better managed in the Bras d'Or and beyond. The efforts underway provide an excellent illustration of what can be achieved when a common purpose, community support, and the right partnerships are in place.

Overview of Environmental Assessment Major Projects in the DFO Maritimes Region in 2008

Ted Potter

In 2008, the Environmental Assessment and Major Projects (EA&MP) Division of DFO's Oceans, Habitat and Species at Risk Branch was engaged in reviewing 25 major projects at various stages of either a *Fisheries Act* review or a Canadian Environmental Assessment. The dollar value of these projects, combined, is in the range of $18–20 billion. Again this year, energy projects represented the principal category reviewed, but mining and marine terminals also were assessed.

The EA&MP's review process involves discussions with developers early in the design process to identify potential adverse environmental impacts and to find ways to address or mitigate them. This often results in redesign of the project, relocating it away from fish-bearing waters or important fish habitat. Timing activities to avoid critical time in the life cycle of fish is another means of mitigating adverse impacts.

The developer often submits an Environmental Impact Statement (EIS) which describes the construction and operation of the proposed development, and their associated environmental impacts. DFO's role is to review the EIS for completeness and accuracy and to assess it against the habitat protection provisions of the *Fisheries Act*, the Policy for the Management of Fish Habitat, and the *Species at Risk Act*. In completing the review, the EA&MP seeks advice and input from other divisions within Oceans, Habitat and Species at Risk Branch, Science Branch via the Centre for Science Advice, Fisheries and Aquaculture Management, and the DFO Area Offices.

The following are brief summaries of a couple of lesser known but nonetheless interesting files:

Melford Container Terminal - Strait of Canso

Melford International Terminals Inc. is proposing to construct the Melford International Terminal (MIT), located at Melford Point in Guysborough County, Nova Scotia. The MIT will consist of a container terminal, rail yard with rail infrastructure, logistics park, and access road and will require realignment of a portion of Highway 344 and involve the infilling and dredging of a large area of marine habitat (upwards of 280,000 square metres [m^2]). In addition, by removing the lower portion of the watershed where the industrial park will be located, the proposal will impact 75,770 m^2 of freshwater fish habitat.

Sydport Container Terminal - Sydney Harbour

The Laurentian Energy Corporation is proposing the construction of a new container terminal in the south arm of Sydney Harbour. The project comprises the dredging of 9.9 km of access channel, a contained disposal facility for dredge spoils (serving as the marine footprint for the terminal), dredging of the terminal berth line, infilling of 24 hectares of marine habitat, and the construction of a spur railway line.

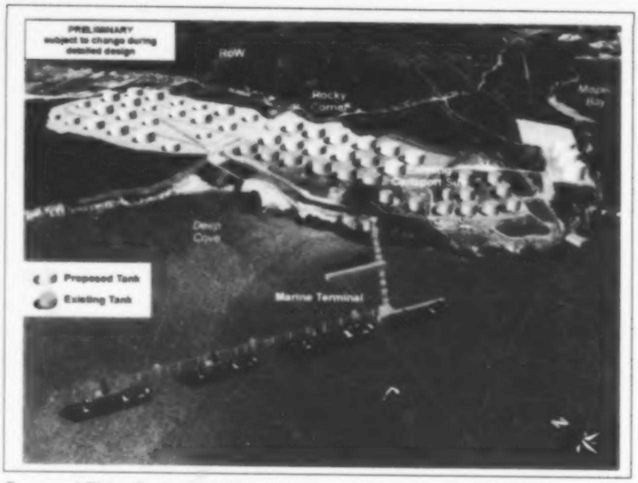
Lake Uist Wind Hydro Facility – Cape Breton

Cape Breton Explorations Limited proposes to construct and operate a hybrid wind-and-hydro pump, storage, and power-generating

facility in the area of Lake Uist in Cape Breton and Richmond counties. It will include a reservoir with the capacity of 20,000,000 cubic meters, two 50-75 megawatt hydro reversible pump turbines, and as many as 44 wind turbines each with a generating capacity of 2.3 megawatts. Power generated from the wind turbine portion of the project will be used to power the pump turbines which will move water from Lake Uist up to the reservoir to be released back into Lake Uist through electricity-generating hydro turbines.

Irving Oil Eider Rock Project – Petroleum Refinery and Marine Terminal

Irving Oil Company Ltd is proposing the construction and operation of a second refinery in Saint John, New Brunswick. The new refinery is anticipated to produce 250,000 barrels per day of refined product, primarily destined for the US market. In addition to the land-based infrastructure, the project will include a new one-km-long marine terminal. It is proposed that the marine terminal will be located west of the current monobuoy (the device used to off-load oil from the oil tankers to the tank farm). Three design options are being considered for the marine terminal, each having a different impact on fish habitat.[1]



Proposed Eider Rock petroleum refinery and marine terminal – image courtesy of Irving Oil Ltd.

EMERGING ENVIRONMENTAL ISSUES

Two emerging files that the EA&MP is tracking are tidal power and preparation for the pending Georges Bank Moratorium review.

Tidal

Nova Scotia and New Brunswick have completed Strategic Environmental Assessments (SEA) for the Bay of Fundy. Nova Scotia is proceeding with plans to establish a test site in the Minas Passage area and New Brunswick is proceeding with a project to map the potential tidal resource in its waters. The EA&MP represents the Maritimes Region in providing input to the SEA process and coordinating the Region's follow-up to the recommendations outlined in the respective reports. We will also be reviewing the environmental assessment for the pilot project in the Minas Basin and have provided advice to the Province of New Brunswick as to the type of environmental data they should collect as they map the tidal resource. (See *BIO Contributes to the Development and Regulation of Canada's Ocean Renewable Energy Conversion Industry*, p.4.)

Georges Bank Moratorium Review

While nothing formal has been announced with respect to a process for reviewing the Georges Bank Moratorium on Petroleum Exploration and Development, preparatory work is underway within DFO to contribute once a process is announced. (The present moratorium expires in 2012.) To that end, a Regional Working Group led by the EA&MP was established to coordinate DFO's input. Members of the working group represent the following DFO sectors: Science, Fisheries and Aquaculture Management, Oceans, Habitat and Species at Risk, Policy and Economics, Communications, and the Southwest Nova Area Office. The purpose of the working group is to oversee, co-ordinate, and provide a one-window approach for DFO's review, compilation, and presentation of information for the Georges Bank Moratorium Review. Key areas of focus are: state of the knowledge on the biological and physical environment of Georges Bank; our current understanding of potential impacts from petroleum exploration and development activities; identification of knowledge gaps and research priorities; and a socio-economic analysis of the fishing industry on Georges Bank.

ABORIGINAL ENGAGEMENT AND CONSULTATION

Prior to concluding the *Fisheries Act* review and preferably during the Environmental Assessment phase, the EA&MP is required to consult with aboriginal groups in the province in question to ensure that there is no infringement of rights and to provide appropriate accommodation if required.

Aboriginal engagement/consultation in the Maritimes Region follows slightly different processes whether the project is in New Brunswick or Nova Scotia.

In New Brunswick, the process consists of communication with 15 First Nations (Mi'kmaq and Maliseet) and umbrella groups such as the Union of New Brunswick Indians representing 12 First Nations and the Mawiw Council representing three First Nations. Contact is made also with the New Brunswick Aboriginal Peoples Council which represents the off-reserve aboriginal population.

In Nova Scotia, engagement and consultation are conducted using the Terms of Reference as outlined in the Made-in-Nova Scotia Process. This negotiation process involves early notification and information on proposed projects, with a letter requesting consultation sent by the Regulatory Authorities to the 13 Chiefs and Councils and copied to the Assembly of Chiefs through the Kwilmu'kw Maw-klusuaqn (KMK) Negotiation Office. If the KMK decides that consultation is needed or desired, a Chief or individual First Nation is selected to lead on behalf of the group. We also consult with the Native Council of Nova Scotia which represents the off-reserve aboriginal population.

In 2008, the EA&MP has engaged First Nations on approximately a dozen projects, e.g., the proposed Lake Uist Wind Hydro facility, about which the five Cape Breton First Nations chiefs have raised concerns with the DFO Minister. Discussions with First Nations are expected to continue as new projects arise.

[1] Author's note: As of July, 2009, this project was placed on hold, due to declining market conditions. However, the environmental assessment is still going forward because the proponent, Irving Oil Company Ltd., would like to have the option to proceed, should market conditions improve.

Technical Support

Research Voyages in 2008

Donald Belliveau

Researchers at BIO utilize the following research vessels based at the Institute and operated by the Canadian Coast Guard (CCG), Maritimes Region:

CCGS *Alfred Needler*, a 50-m offshore fisheries research trawler;
CCGS *Hudson*, a 90-m offshore research and survey vessel;
CCGS *Matthew*, a 50-m coastal research and survey vessel.

In addition, BIO scientists conduct field programs on CCG research vessels from other DFO regions, vessels of opportunity (e.g., CCG buoy tenders and icebreakers, commercial fishing ships, and survey ships), and research vessels of other countries. The CCGS *Creed*, based in Quebec Region, was used by NRCan's Geological Survey of Canada (GSC) for multibeam survey work in the Gulf of St. Lawrence and Bay of Fundy. Surveys normally conducted on the CCGS *J.L. Hart*, a 20-m inshore research vessel, were conducted on a series of charter vessels in 2008 because the *Hart* was removed from service and the replacement vessel was not yet available.

The CCGS *Alfred Needler's* principal role is stock assessment surveys. Most programs usually conducted on the *Needler* were conducted on the *Wilfred Templeman* and the *Teleost* out of St. John's, Newfoundland and Labrador (NL) because the *Needler* was out of service for her Transitional Life Extension, an extended refit that will upgrade the vessel's systems as well as add considerable oceanographic science capabilities in preparation for the planned reduction from three to two trawlers. The *Needler* returned to service in October and assisted with NL Region's fall survey.

The CCGS *Hudson* started her year in early April. The first cruise was for the Maritimes Region annual spring Atlantic Zone Monitoring Program (AZMP). This cruise collects data on water properties, temperature, salinity, nutrients, dissolved oxygen, and plankton biomass for the annual *State of the Ocean Report* and for focused research projects. The second cruise serviced moorings in Orphan Basin and Flemish Pass off Newfoundland. The vessel then sailed to the Labrador Sea to service oceanographic moorings and collect conductivity, temperature, and depth data in oceanographic survey operations, as part of Canada's contribution to global climate studies. During a June cruise, scientists conducted video surveys for benthic research over a moraine in The Gully Marine Protected Area and in Haldeman and Shortland canyons on the edge of the Scotian Shelf. The cruise was completed with a return visit to the Banquereau clam dredging experiment site to investigate recovery of the benthos in the dredged areas.

The Natural Sciences and Engineering Research Council of Canada sponsored the *Hudson's* next cruise which was led by researchers from Dalhousie University. Heat probes were lowered into the seabed to study physical properties of sediment at the lower edge of the Eastern Scotian Shelf. In July, the ship went to the Terra Nova offshore oil field for investigations into the impacts of produced water on the environment around the platform. (Produced water is recovered with the oil as it is brought from deep underground.) NRCan used the ship in July for geophysical research on the Labrador Shelf. They conducted sidescan surveys, piston coring, bottom photography, grab sampling, and seismics for geophysical research. The vessel changed crews in Nain and headed north to complete the joint NRCan-University of Montreal program that had been cancelled the year before. The program included all the sampling of the cancelled cruise along with physical oceanographic sampling for the university researchers. The *Hudson* was the farthest north she has been in many years, reaching 72.5° north latitude. The Maritimes Region fall AZMP cruise was conducted in October; following that, from late October to mid-November, oceanographers from the Institut Maurice Lamontagne in Quebec Region conducted their fall AZMP/Ice Forecast cruise in the Gulf of St. Lawrence. From late November to mid-December, the *Hudson* was used to conduct the fall AZMP cruise of the Northwest Atlantic Fisheries Centre in St. John's, NL. The season concluded December 13 when the ship was docked at BIO for the winter.

The CCGS *Matthew* is primarily a hydrographic vessel which can carry two hydrographic launches and conduct surveys with its high-resolution Kongsberg EM710 multibeam sonar system. After local trials in May, the *Matthew* conducted surveys off Cape Breton and in unsurveyed waters around Penguin Island off the south coast of Newfoundland. This was the first year of a multi-year survey in the

The CCGS *Louis S. St.-Laurent* tied up at the BIO wharf while it unloaded gear from the UNCLOS Arctic program, side-by-side with the CCGS *Hudson*

area. In June, the *Matthew* moved to the north coast of Newfoundland to continue surveys in Bonavista Bay and around Fogo Island and headed for the Labrador coast in July. All outstanding work in the approaches to Cartwright was completed. In August, NRCan conducted the third year of studies on iceberg scours on Makkovik Bank. The vessel spent from mid-August to mid-September surveying to expand the safe shipping channels in the Voisey's Bay area. From mid-September until early November the *Matthew* conducted a joint CHS-NRCan survey in the Bay of Fundy. On November 5, the *Matthew* returned to BIO for the winter.

Replacement of our ageing scientific research fleet is a high priority. Plans are underway to replace the *J.L. Hart*; preliminary design work was started in 2006. Delivery is expected in 2011. Two replacement trawlers, one for each of the east and west coasts, were announced in the spring 2005 federal budget. Contracts have been let to start the preliminary design, with delivery planned for 2012. The replacement for the *Hudson* is moving ahead with completion of the Statement of Requirements expected in early 2009 and delivery of the ship in 2013.

Hydrographic launch, *Pipit*, from the CCGS *Matthew*, surveying in Scots Bay in the Bay of Fundy

DFO Outreach

Tom Sephton

BIO visitors enjoy the Species-at-Risk display

BIO summer tour guides, Kathryn Cook (left) and Sarah Shiels

The BIO Outreach Program is managed by DFO and is based on the philosophy that ocean education is essential and we shall endeavour to translate research at the Institute to a level easily comprehended by the general public. In particular, the BIO Ocean Education Centre displays are targeted to enhance and add to the current suite of Nova Scotia public education venues (e.g., the Maritime Museum of the Atlantic). In 2008, an effort was made to promote marine biodiversity, the value and understanding of marine and aquatic habitats and environments, the value of ecosystem research (biological, chemical, and physical), and the role of geosciences in ocean management.

Now in its 13th year, the BIO Outreach Tour Guide program has successfully reached thousands of local and international visitors. Tours are offered to individuals of a variety of ages and backgrounds, and some visitors return year after year. The majority of visitors are ages 6-12; their teachers and day camp leaders often comment that BIO offers children a fun and educational opportunity to explore ocean science. In 2008, over 5,400 people were booked for tours given by the two tour guides. As well, special tours were given to groups by BIO Outreach volunteers. The groups, from a variety of backgrounds, included the Ocean Tracking Network; ICOM World Maritime University; Canadian Mortgage and Housing Corporation Directors; delegates from the ICES Annual Science Conference; Nova Scotia Business Inc with a delegation from Croatia; and a group representing International Trade, the National Research Council-Industrial Research Assistance Program, and the Atlantic Canada Opportunities Agency with a delegation from Ireland.

Education Outreach at the Geological Survey of Canada (Atlantic) during the International Year of Planet Earth

Jennifer Bates, Sonya Dehler, Gordon Fader, Rob Fensome, David Frobel, Nelly Koziel, Bill MacMillan, Bob Miller, Michael Parsons, Patrick Potter, John Shimeld, Bob Taylor, Dustin Whalen, and Graham Williams

During 2008, the International Year of Planet Earth (IYPE), the GSC Atlantic of NRCan participated in several exciting regional and national education activities. GSC Atlantic staff are leading the development of a popular book on the geology of Canada. *Four Billion Years and Counting: Canada's Geological Heritage* (FBY) will bring together the expertise of much of the Canadian geoscience community. Soon to be co-published by the Canadian Federation of Earth Sciences and a commercial publisher, the FBY book is a cornerstone of Canada's contribution to the IYPE. The book project website is (www.cfes-fcst.ca/fby). Other key activities in Canada's IYPE program are: Geo-time Trails; the WHERE challenge for high school students (www.earthsciencescanada.com/where); and a careers website

The EDGEO Workshop:

"This workshop was well worth taking. I am inspired, armed with activities and thought-provoking questions to use in class. Thank you so much!"

GSC Atlantic staff at Silver Sands Beach, foreground: Bob Taylor (2nd from left) and Bill MacMillan (right)

The GSC's Bill MacMillan and Michael Parsons (right) at Montague Gold Mines

Education Outreach at the Geological Survey of Canada (Atlantic) during the International Year of Planet Earth

Jennifer Bates, Sonya Dehler, Gordon Fader, Rob Fensome, David Frobel, Nelly Koziel, Bill MacMillan, Bob Miller, Michael Parsons, Patrick Potter, John Shimeld, Bob Taylor, Dustin Whalen, and Graham Williams

During 2008, the International Year of Planet Earth (IYPE), the GSC Atlantic of NRCan participated in several exciting regional and national education activities. GSC Atlantic staff are leading the development of a popular book on the geology of Canada. *Four Billion Years and Counting: Canada's Geological Heritage* (FBY) will bring together the expertise of much of the Canadian geoscience community. Soon to be co-published by the Canadian Federation of Earth Sciences and a commercial publisher, the FBY book is a cornerstone of Canada's contribution to the IYPE. The book project website is (www.cfes-fcst.ca/fby). Other key activities in Canada's IYPE program are: Geo-time Trails; the WHERE challenge for high school students (www.earthsciencescanada.com/where); and a careers website

The EDGEO Workshop:

"This workshop was well worth taking. I am inspired, armed with activities and thought-provoking questions to use in class. Thank you so much!"

GSC Atlantic staff at Silver Sands Beach, foreground: Bob Taylor (2nd from left) and Bill MacMillan (right)

The GSC's Bill MacMillan and Michael Parsons (right) at Montague Gold Mines

The AGS-Photographic Guild of NS field trip to Kejimkujik's Seaside Adjunct site

(www.earthsciencescanada.com/careers). For information on projects in Canada, visit the IYPE website (www.earthsciencescanada.com/iype).

Much of the education outreach by the GSC Atlantic is as a contributing member to the EdGEO, Video, and Education committees of the Atlantic Geoscience Society (AGS). Other members of these committees include provincial geological surveys, museums, science centres, universities, and schools. As well as participating on these committees, staff give invited talks at schools, universities, and libraries and judge at science fairs.

In December 2008, the AGS collaborated with the Discovery Centre, *The Chronicle-Herald*, and Encana to develop an education supplement. The AGS contributed its geoscience and education expertise to a cartoon script titled *Where on Earth does your stuff come from?* A copy of the supplement was given to every grade seven student in Nova Scotia; for their teachers, a lesson plan was developed and made available on *The Chronicle-Herald* website. Learning activities and glossary terms from EarthNet (www.earthnet-geonet.ca) formed the bulk of this document.

EdGEO is a national program that supports local workshops on earth science for Canadian teachers. The Nova Scotia EDGEO Committee now divides its program between a field-based workshop and hands-on sessions at the NS Association of Science Teachers annual conference in Halifax. These changes to the Nova Scotia EdGEO program provide flexibility for current presenters, growth for new session organizers, and best of all, more professional development opportunities for teachers.

The August 2008 two-day field trip, hosted by NRCan at BIO, was the 16th EdGEO workshop since 1994. The field trip, "Environmental Geology of Halifax and Surrounds" introduced the participants to several interesting geological sites and the relevant environmental issues. HRM sites in Bayers Lake Business Park and the Waterstone Subdivision offered the opportunity to tell the tale of geology and urban residential development. Acid rock drainage and its mitigation is a key issue in these areas. A superb granite outcrop along Highway 103 was the focus of granitic melts and incompatible elements. Uranium, radon, radio-nuclides, and fluorosis were the

Geophoto meetings bring together photographers and geologists so they can exchange their expertise. At the annual Photo Guild of NS competition, Wayne Garland received the AGS The Last Billion Years Award (for best Atlantic Canada geological photograph), for this photograph of the Five Islands area of NS. Photo is courtesy of Wayne Garland.

environmental topics. On day two, a tour of the Halifax Wastewater Treatment Plant gave participants the chance to consider the issues of sewage, metals, organic contaminants, and water quality. The afternoon stops were at Silver Sands Beach, where long-term development has greatly influenced the barrier beach system, and Montague Gold Mines, where historical mining continues to influence the current environment and the community surrounding the old gold mining district. The evening session at BIO provided better understanding of our beaches and the dominating feature of Halifax—its harbour. The positive feedback suggests that the environment is a common ground where geologists can connect with other educators.

Financial support for the August workshop came from the National EdGEO Committee. In-kind support was generously provided by the GSC Atlantic, the Nova Scotia Department of Natural Resources, BIO, the Nova Scotia Museum of Natural History, the Nova Scotia Community College, the Halifax Independent School, several NS public schools and school boards, and the Atlantic Science Links Association. The success of the program depends upon the knowledge, experience, enthusiasm, and dedication of its committee, whose members represent the geoscience and education communities in the above organizations.

GSC staff continued to volunteer in ongoing education programs in 2008, including the "Beyond *The Last Billion Years*" talk series at the Nova Scotia Museum of Natural History; participation in the Halifax Young Naturalist Club; and collaboration with photographic clubs, particularly the Bridgewater Camera Club and the Photographic Guild of Nova Scotia, to introduce their members to photogenic geological sites.

One of the success stories in 2008 was financial support from Encana Corporation for development of energy-related content for the EarthNet website. Although the site has a national scope, the development committee is located in Nova Scotia with the majority of its members at the GSC Atlantic.

All of the above-mentioned activities and programs are possible only with the assistance of members of the Nova Scotia Branch of the AGS Education Committee.

Dedication of the Katherine Ellis Laboratory

Sherry E. H. Niven and John N. Smith

The east side of the Katherine Ellis Laboratory

On October 15, 2008, BIO's new laboratory building was officially opened and dedicated to the memory of Katherine (Kathy) Ellis, a key member of the BIO community for over 20 years.

The Katherine Ellis Laboratory provides much needed, modern laboratory facilities for the Institute and was designed to meet program requirements. Other design considerations included the site's topography, connection to the Institute's other buildings and jetty, and energy efficiency. The laboratory makes use of heat recovery technology and takes full advantage of BIO's Energy Centre, which extracts cool water from the Bedford Basin for air-conditioning of the complex.

Seventy-two laboratory modules on three floors have been tailored for current DFO, NRCan, and EC programs at BIO. If future changes are required, the building design will allow this to be done without making costly alterations to the ventilation system and utilities. Co-locating labs from the three federal science departments at BIO makes good sense in terms of space use, and also facilitates the collaboration central to BIO's success as a research institute.

Kathy Ellis's name was chosen for the new laboratory by BIO staff and management as a tribute to her and her many contributions to the science and spirit of the Institute.

Shortly after receiving her Masters degree in Chemistry from Dalhousie University in 1978, Kathy joined the Chemical Oceanography Division of BIO to establish a marine radioactivity laboratory and environmental monitoring program. Through this work, she developed new techniques for measuring radioactivity in seawater that led to her involvement in a wide range of international projects using natural and artificial radionuclides to gain information about water circulation, particle transport, and sedimentation.

In 1983, Kathy began an exciting and influential career in Arctic studies at the Canadian Expedition to Study the Alpha Ridge (CESAR) Ice Station, about 300 km south of the North Pole. Followed by expeditions to Greenland in 1984 and the Canadian Ice Island (north of the Canadian Archipelago) in 1985, 1986, and 1989, her work resulted in the foremost radioactivity data set in the Arctic Ocean during the 1980s. In 1993, Kathy led an expedition aboard the Russian vessel, RV *Geolog Fersman*, to study plutonium contamina-

tion from nuclear weapons tests, and, in 1994, she led the marine radioactivity team during the historic Arctic Ocean Section mission on the CCGS *Louis S. St-Laurent* that involved the first transit of scientific vessels across the Arctic Ocean via the North Pole.

Kathy had a particular interest in teaching and technology transfer in developing countries. Between 1988 and 1991, she undertook three visits to China sponsored by the International Development Research Centre and established a sediment dating facility in the Department of Geo-Marine Sciences at Nanjing University. She also helped organize an oceanographic study on the environmental impacts of harbour development in the burgeoning cities of Sanya and Yangpu in Southern China. This program necessitated the three-day re-configuration of an old 1940s coastal ferry boat into a "modern" oceanographic vessel and resulted in the first seismic reflection studies and marine radioactivity measurements on Hainan Island in Southern China. Kathy was well known for her sea-going prowess and never failed to impress even the "hardened" crew members of foreign vessels with her resilience and oceanographic expertise.

In the late 1990s, Kathy organized several workshops on radiochemistry in Istanbul, Turkey and Manila, The Philippines that were sponsored by the International Atomic Energy Agency and designed to introduce graduate students and research scientists to modern radioanalytical techniques.

Kathy was also very active at home – in BIO events, science outreach, the community-at-large, and working toward the full participation of women in science. She lived life well and to the fullest.

Naming BIO's new laboratory after Kathy is certainly a deserving and fitting tribute. Kathy knew very well the importance of public visibility of successful, influential, and respected woman scientists. Her outreach work focused on increasing public awareness of the important contributions women regularly make in a wide range of scientific fields and in promoting scientific research as an exciting career for women.

Also, Kathy loved her work and the multidisciplinary, team nature of working at BIO. She would be honoured that her peers have chosen her name for the facility that now houses the environmental radioactivity laboratory she established, as well as the laboratories of other BIO chemists, biologists, and geologists with whom she worked.

The Institute's many achievements over its 46-year history are a result of the philosophies that epitomize BIO, philosophies that Kathy put into practice: dedication to high-quality research, the importance of the BIO "team" and multi-faceted collaborative projects, and a passion for making a contribution to the marine science community and Canada.

Katherine M. Ellis (10 May 1953 – 23 July 1999)

From left: Faith Scattolon, DFO Maritimes Regional Director-General; Evelyn Ellis, Kathy's mother; and Wendy Watson-Wright, Assistant Deputy Minister, DFO Science unveil the dedication plaque in the Katherine Ellis Laboratory.

ICES 2008 Annual Science Conference

Thomas W. Sephton

Her Excellency, the Right Honourable Michaëlle Jean opened the ICES conference. She is welcomed by BIO Director, Michael Sinclair and the DFO Assistant Deputy Minister of Science, Wendy Watson-Wright. Photo courtesy of MCpl Jean-François Néron, Rideau Hall

The DFO Maritimes Science Branch hosted the International Council for the Exploration of the Seas (ICES) Annual Science Conference (ASC) at the Halifax World Trade and Convention Centre, September 22-26, 2008 (www.ices.dk/iceswork/asc/2008/index.asp). ICES is an independent scientific organization based in Copenhagen, Denmark. Its mission is to provide unbiased, sound, reliable, and credible scientific advice on human activities affecting, and affected by, marine ecosystems (particularly in the North Atlantic Ocean and the Baltic Sea). This was the third time that Canada hosted the event, which previously was held in Montreal (1975) and St. John's (1994). The occasion for hosting this year's conference was to join in celebrating 100 years of Canadian marine research; anniversary celebrations were also held at the Pacific Biological Station (Nanaimo, BC) and the St. Andrews Biological Station (SABS) (St. Andrews, NB), which both opened in 1908. The issues at the birth of ICES (1902) and of Canadian marine science (1908) were climate variability and the over-fishing debate—the same issues we face today: climate change and the ecosystem sustainability debate.

The official registered attendance at the ICES ASC was 651 but more than 700 conference bags were issued, to mostly Europeans

Canada's Governor General addresses the ICES conference.

The Nova Scotian Celtic group, Bracken, provided the music for the opening ceremony.

from ICES member countries. The scientific program for this ASC was solid and, through a mix of speakers and panel discussions, dealt with many issues facing maritime nations today, ranging from climate change and Arctic ice to the use of marine protected areas. Of the many highlights of the ASC, the opening ceremony was truly memorable with Her Excellency, the Right Honourable Michaëlle Jean, Governor General of Canada, giving the Keynote Address (www.gg.ca/media/pho/index_e.asp?GalleryID=540). The opening reception was well attended, as old friendships were rekindled and new ones initiated.

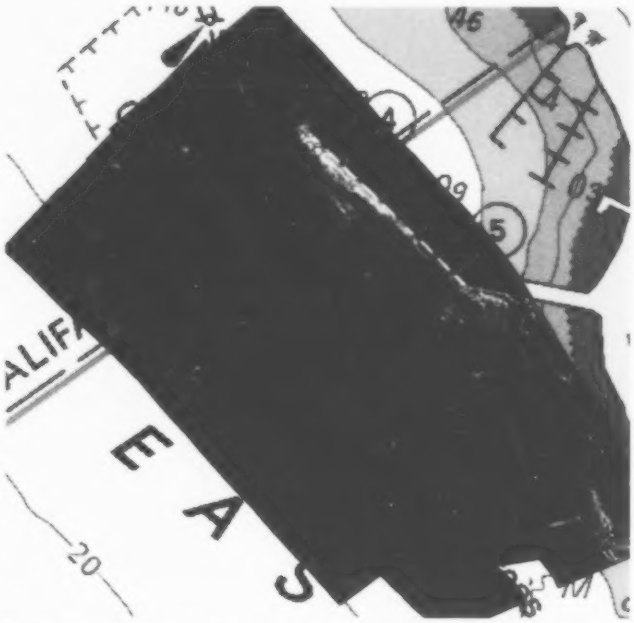
A record 251 delegates attended the conference banquet at historic Pier 21 on the Halifax waterfront and were entertained by the precision drum and bagpipe quartet 'Squid'. The weather that week couldn't have been better for enjoying the partner-spousal daytrips around the south shore and Halifax Regional Municipality, a guided tour of BIO, the Young Fishers/Scientists trip to Pubnico, and the attractions of downtown Halifax. The conference was an all-around success, thanks to the 64 volunteers from BIO and SABS who "gave it their all with a smile" so that everything went off without a hitch all week.

Michael Sinclair (BIO), Joe Horwood (ICES, UK), Gerd Hubold (General Secretary, ICES), Governor General Michaëlle Jean, Wendy Watson-Wright (DFO), Tom Sephton (BIO), Serge Labonté (DFO, Ottawa), and Angus MacIsaac (Deputy-Premier of Nova Scotia), at the ICES conference – photo courtesy of MCpl Jean-François Néron, Rideau Hall

ICES delegates tour BIO, led by BIO Scientist Emeritus, Richard Eisner (right).

Highlights of 2008 at the TRINITY MARLANT Route Survey Office

Lt(N) Jason Karle and PO2 Marilyn Gilby



Example of a Halifax Force Protection survey of Naval Jetty NS located at Fleet Diving Unit Atlantic: the red circles indicate objects meriting further investigations.

BIO hosts a few people wearing the Naval uniform of the Canadian Forces. They are a part of MARLANT (Maritime Forces Atlantic) TRINITY, which provides the navy with surveillance and intelligence data and is the primary source of information, from weather to current world events, for the East Coast fleet. At BIO, our association is primarily with the Canadian Hydrographic Service (CHS). The principal role of the Route Survey Office (RSO) is to provide ocean mapping information in order to identify changes on the bottom, mainly in the event of naval mining. Mines come in many shapes and sizes so the resolution and accuracy of the information are very important. Mine-like objects are investigated and information saved in a database. If an area is thought to be mined it is re-surveyed and changes to the bottom are then investigated.

The Route Survey Office is also involved in search-and-rescue operations (most recently locating a crashed search-and-rescue helicopter near Canso), collection of baseline data (both side-scan and multi-beam bathymetry), and the location of targets of interest (Avro Arrow test models in Lake Ontario and the HMCS *Shawinigan*).

In 2008, TRINTY RSO:

- Surveyed potential Submarine Bottoming Areas, with the CHS and Defence Research and Development Canada (DRDC), collecting magnetic, multi-beam sonar, and penetrometer information. This provided an opportunity for the joint sharing of information and effort;
- Hosted two side-scan sonar courses, primarily focused on operator training for naval personnel;
- Participated in the bi-national Frontier Sentinel exercise in Portsmouth, New Hampshire conducting side-scan survey and processing the collected data. Participants included: the Canadian Forces, DRDC, National Oceanic and Atmospheric Association, United States (US) Navy, US Coast Guard, numerous Canadian and American law enforcement agencies, and other government agencies involved in Homeland Defence;
- Performed jetty surveys in support of Halifax Force Protection in advance of visiting foreign warships;
- Conducted a multi-beam survey from the CCGS *Matthew* near Port Aux Basques, Newfoundland and Labrador in the effort to locate the WWII wreck of the HMCS *Shawinigan* (see article by Lt(N) Karle); and
- Participated in the Canadian Fleet Exercise surveying areas around Halifax, simultaneously deploying in two ships with two survey and processing teams. Surveying and processing, both at sea, allowed for increased productivity and trialing of various methods to efficiently transmit raw and processed data to other units and shore authorities—a significant challenge when considering the potential size of the data files.

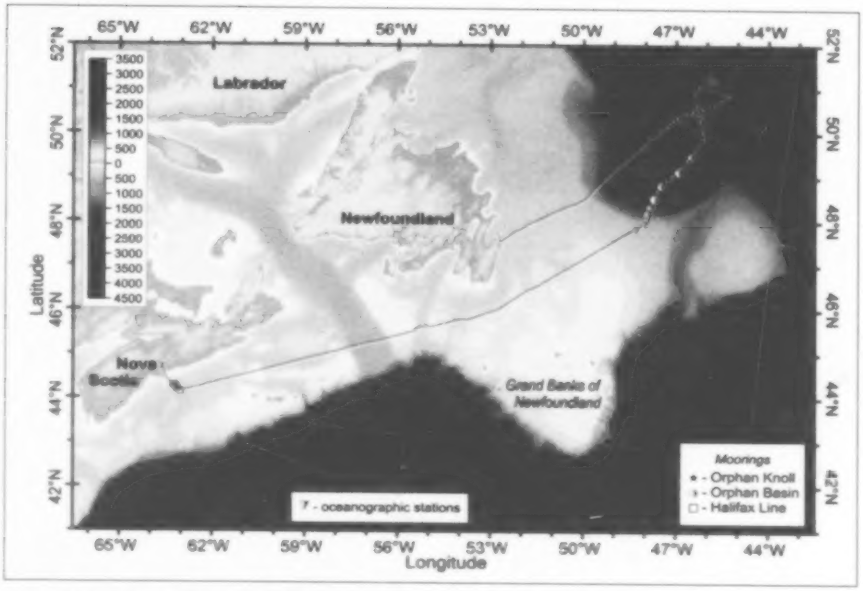
Highlights and New Initiatives

INTERNATIONAL GOVERNANCE STRATEGY — NORTHWEST ATLANTIC SEAMOUNTS

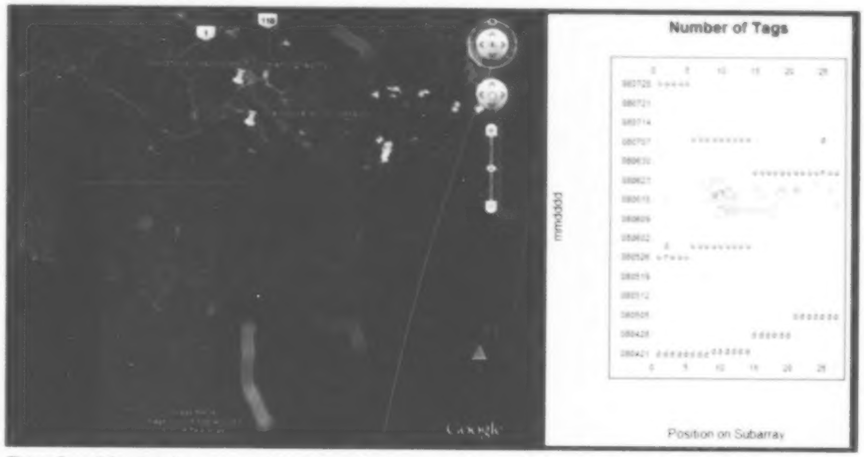
The DFO International Governance Strategy (IGS) has been established to support the international governance of fisheries, healthy ocean ecosystems, and Canada's economic and environmental interests in the high seas. An IGS-funded project was initiated in 2008 to provide an oceanographic characterization of seamounts and other ocean areas, which are currently under, or being considered for, a precautionary closure to fisheries because of their potential ecological vulnerability. A seamount is a mountain which rises at least 1000 m above the seafloor but does not reach the ocean's surface. Indeed, the peaks are often hundreds to thousands of metres below the surface, and are therefore considered to be within the deep sea. An estimated 30,000 seamounts occur across the globe, with only a few having been studied.

During the project's first year, collection and analysis of oceanographic data from Orphan Knoll, a seamount east of Newfoundland

were carried out to complement a benthic habitat survey planned for 2009. Results from this research will help determine the uniqueness, interconnectivity, and vulnerability of the ecosystems over particular seamounts off Atlantic Canada,



Track of CCGS *Hudson* cruise HUD2008006 (red line) which included a survey of Orphan Knoll in May 2008: location of near-bottom moorings are indicated. Water depth in metres is indicated by the color bar in the upper left of the figure.



Thirty-four Atlantic salmon were detected moving eastward, in transit from the Bay of Fundy/Gulf of Maine and the LaHave River. (a) Detections locations (red dots) on the pilot version of the Halifax Line (yellow and red dots); size of red dot is proportional to the number of detections at that location (Tag data courtesy of NOAA, USGS, and DFO); (b) Timing of detections (vertical scale) on the pilot line as a function of station number, 1-27 (horizontal axis). Most detections occurred in mid-June between the 60m (stn.7) and 100m (stn.21) isobaths. A current mooring was in place to the east near the end of the pilot line from early April onward.

INAUGURATION OF THE OCEAN TRACKING NETWORK ON THE HALIFAX LINE

In February, Dalhousie University was awarded $35M from the Canadian Foundation for Innovation (CIF) for infrastructure to support the Ocean Tracking Network, a global array of acoustic curtains, consisting of close-order lines and grids of bottom-mounted hydrophones for the detection of acoustic tags that have been surgically implanted into individuals of various species of marine fish and mammals. By analyzing and comparing detection data from different curtains, critical migration patterns, queues, timings, and other characteristics can be deduced and used to understand the marine ecosystem and manage and protect important fisheries or threatened species. The Natural Sciences and Engineering Research Council (NSERC) announced its intention also to grant university scientists up to $10M in support of tagging projects for particular species of interest.

From the outset, DFO scientists have been involved in the CIF infrastructure project, through DFO's commitment to deploy and maintain the infrastructure for the Canadian portion of the network (including curtains on the Scotian Shelf and in the Gulf of St. Lawrence) and in the NSERC project, through research collaboration with the universities. In particular, BIO scientists and technicians have been involved in deploying and maintaining an array of physical oceanographic instruments on the inaugural Halifax Line, to provide environmental data that complement the tracking data. The Halifax Line runs southwesterly from the coast at Chebucto Head. Other BIO fisheries scientists have been tagging important species (e.g., Atlantic salmon and haddock) in hopes of understanding their movements and behaviour.

In spite of funding delays, some initial progress has been made on the installation of an acoustic curtain on the Halifax Line, with support from Dalhousie University and DFO. A pilot line of about 30 hydrophone moorings at 800-m spacing has been deployed between the coast at Chebucto Head (near Halifax) and the vicinity of Station HL2 (at around 150-m depth) on the Halifax Line. Detections of Atlantic salmon from the Gulf of Maine and LaHave River on the pilot line during the period of April-July, 2008 have been clustered in both time (mid-June) and space (60-100-m depth). This apparently coordinated transit of salmon that left their widely spaced river environments at different times suggests a schooling activity somewhere west of the Halifax Line prior to migration. Moreover, monthly mean currents recorded at a nearby mooring suggest that currents opposing the eastward migration are weakest in June, a fact that generates further hypotheses regarding environmental influences on fish behaviour.

FEDERAL-PROVINCIAL COLLABORATION ON SOCIAL, CULTURAL, AND ECONOMIC OBJECTIVES FOR INTEGRATED OCEANS AND COASTAL MANAGEMENT

DFO is required to lead and facilitate the development of integrated management plans for Canada's oceans. Integrated management is

a process aimed at addressing multiple, and potential, competing uses in the oceans, while considering impacts from these activities at an ecosystem level. Through developing integrated management initiatives, such as the Eastern Scotian Shelf Integrated Management Initiative, DFO has recognized that integrated management includes social, cultural, and economic considerations, as well as ecosystem aspects. Information on these human aspects is required for successful management of large ocean management areas, and is important in the development of objectives for integrated management. As such, DFO Maritimes Region initiated a process to develop a Social, Economic, Cultural Overview and Assessment (SECOA) Report for the entire Scotian Shelf. In March 2008, a consultant to DFO's Oceans and Coastal Management Division completed the *Assessment of Quantitative and Qualitative Data and Information for the Social, Economic and Cultural Overview and Assessment of the Scotian Shelf*. The report identifies and assesses quantitative and qualitative data and information required to compile a Scotian Shelf SECOA Report.

In April 2008, a one-day workshop was held at BIO to determine the way forward on the SECOA initiative. Workshop objectives were to:

- present and discuss outcomes of the contract to assess quantitative and qualitative social, economic, and cultural data and information for the Scotian Shelf;
- discuss use and sharing mechanisms of such data and information, as well as the linkages between SECOA and related federal and provincial initiatives;
- discuss scaling and application of the data and information for ocean management, planning, and decision-making, from the site-specific scale to regional scale;
- determine next steps in the drafting of the Scotian Shelf SECOA Report, including potential collaboration.

A data CD accompanying the data assessment report was distributed to federal and provincial colleagues at the Rural Secretariat, the Nova Scotia (NS) Department of Fisheries and Aquaculture, and the NS Department of Finance's *Community Counts*, for web mapping applications. Linkages have been made with efforts at the NS Department of Fisheries and Aquaculture to complete a State of the Coast Report for NS in 2009. Discussions have also been held with colleagues on the partnering opportunities for a collaborative SECOA initiative (e.g., federal/provincial/academic/NGO) to complete the Scotian Shelf SECOA Report.

RAPID

DFO Science has entered a new partnership with the Proudman Oceanographic Laboratory, Liverpool, United Kingdom, for collaboration in the 2008-2013 phase of the international Rapid Climate Change program (referred to as RAPID). Scientists in the Ocean Sciences and Ecosystem Research divisions will be collaborating in moored and survey measurements of the Deep Western Boundary Current along the Scotian Rise off Halifax. The resulting observations will be used to describe variability in the ocean climate off Atlantic Canada, and in the North Atlantic's Meridional Overturning Circulation which is an important component of the global climate system.

Workshops and Special Meetings

The first **Societal Applications in Fisheries & Aquaculture using Remotely Sensed Imagery (SAFARI) International Workshop** titled *International Workshop on the Use of Remotely Sensed Data as an Aid to Fisheries Research and Fisheries Management* was held at BIO March 26-28. Forty-four international experts in fisheries and Earth observations attended. The participants, representing over a dozen countries, presented more than 20 lectures on the field of remote sensing and its application to management of sustainable fisheries and aquacultures.

During the workshop, researchers in Earth observations presented background information and promoted existing networks for dissemination of remotely sensed data. Some applications of ocean observations to management of fisheries were presented by the participants. The following are examples:

- *Improvement of fisheries operation*: Presentations were about the successful initiatives of the Indian government to identify potential fishing zones from remotely sensed images and the communication of the information to the local fishermen, and about the fruitful relationships between artisanal fishermen and government scientists in Japan toward increasing the efficiency of the fishing effort.
- *Assessment of fish stock health, growth, and recruitment*: Ocean observation has proven to be useful in the assessment of white hake recruitment off the coast of Newfoundland, shrimp growth in the Northwest Atlantic, haddock survival in the Northwest Atlantic, and stock assessment and by-catch reduction of loggerhead turtles in the Pacific Ocean.
- *Ecosystem dynamics*: Fish catch at the global level was related to temperature, chlorophyll, and primary production estimated from remotely sensed data. Implications of climate change in the large marine ecosystems were also discussed.

In addition to the lectures, participants exchanged views on two main topics: ecosystem indicators and information systems for fisheries operations. The agenda, participants' list, and outline for the International Ocean Colour Coordinating Group monograph are available on the SAFARI website (www.geosafari.org). The meeting was dedicated to David Cushing, a leading light in this field, who passed away just before the symposium.

The **Atlantic Canada Coastal and Estuarine Science Society (ACCESS)** held its **2008 Workshop and General Meeting** at BIO in May. ACCESS is an affiliate of the Coastal and Estuarine Research Federation (CERF). CERF is an international federation that encompasses seven affiliated societies. The membership of ACCESS is composed of researchers from government, academia, and industry; graduate and undergraduate students; representatives from non-government organizations; resource managers; and individuals committed to the science of studying and managing coastal and estuarine habitats in Atlantic Canada. The Society's mission is:

- to promote research in the estuarine and coastal waters of Atlantic Canada

These SAFARI workshop participants include several scientists from BIO.

- to promote communication on matters related to aquatic science in Atlantic Canada
- to gather and disseminate scientific, technical, and other information about estuaries and the coastal zone to Society members and the general public through meetings and publications
- to encourage the teaching of coastal and estuarine science in colleges and universities.

The theme of the 2008 Workshop was *Where the People Meet the Ocean: Nearshore Studies*. More than 110 participants heard over 50 oral presentations and viewed more than 20 posters during sessions on General Nearshore Studies, Sediment Dynamics, Habitat Mapping, Estuarine Eutrophication, Contaminants, and Invasive Species. The 2009 meeting will be held at the University of Prince Edward Island.

Mark Hanson of DFO's Gulf Region illustrates a point during an oral presentation at ACCESS 2008.

The 2008 **Ecosystem Studies of Sub-Arctic Seas (ESSAS) Annual Science Meeting** (ASM) was held in Halifax, September 15-17. A meeting of the ESSAS Science Steering Committee followed on September 18-19. The ASM was opened with welcoming remarks from the host, Erica Head of BIO, and the ESSAS Co-chair, George Hunt of the University of Washington. A round of self-introductions by the fifty-six participants from seven countries followed. Consistent with the goal of the ESSAS program—*to compare, quantify and predict the impact of climate variability on the productivity and sustainability of Sub-Arctic marine ecosystems*—the meeting agenda was divided into sessions to present ongoing research efforts of ESSAS working groups. Session 1 reviewed results from workshops held during the 2007 ESSAS Annual Science Meeting in Hakodate, Japan, which covered three topics: Hotspots, Thresholds, and Ice Models. Papers addressing the two former topics are nearing completion, while modeling studies on the third are continuing. Session 2 was a workshop (convened by BIO's Ken Drinkwater) to examine the importance of advective processes in Sub-Arctic Seas. Session 3 was a workshop which examined climate forcing of marine ecosystems, a follow-up to one held on the same topic in 2007 in Hakodate. The latter workshop was designed to consider types of ecological responses to future climate change, review IPCC models and their relevance to Sub-Arctic Seas, and discuss down-scaling the results of these models to regional models. Session 4 was a workshop on modeling ecosystem responses in a series of Sub-Arctic Seas using the same ecosystem model, ECOPATH. At the Scientific Steering Committee meeting, a new working group was established: Gadoid-Crustacean Interactions will examine climate effects at upper trophic levels, including regime shifts, such as have been observed in the Bering Sea and Newfoundland/Labrador Shelf ecosystems.

The **Seventh International Workshop on Unstructured Grid Numerical Modelling of Coastal, Shelf and Ocean Flows** was held at BIO September 17-19. Eighty-four participants from ten countries on four continents attended, including 28 Canadians from across the country. The workshop was an opportunity for ocean and atmospheric scientists and modellers interested in unstructured grids to discuss theories, results, and applications. As part of the workshop, an open session was held to give the local scientific community a wide-ranging overview of capabilities and challenges in this field. Presentations varied from the development of the pure mathematical underpinnings of the science to the very practical application of various models. Examples of the latter include the storm surge modelling for the Gulf of Mexico (Katrina), determining bay management areas for Canada's aquaculture industry, and tidal correction of TOPEX/Poseidon satellite altimetry in the global ocean. As always, this workshop furthered national and international collaboration and cooperation. The next workshop will be held in September 2009, in Louvain-la-Neuve, Belgium.

A five-day national **Workshop on the Impacts of Seals on Fish Populations in Eastern Canada** was held in Halifax in November on topics related to the potential impacts of seals on fish stocks in Eastern Canada. The meeting was attended by 30 invited participants from Canada, Norway, and the United States of America. Members of the fishing industry, graduate students from Dalhousie University, and interested scientists from BIO also attended. Don Bowen of DFO's Population Ecology Division chaired the workshop. Seals are hypothesized to have five kinds of negative natural effects on prey populations:

1. predation
2. competition
3. transmission of parasites causing increased mortality of fishes
4. disruption of spawning causing reduced reproductive success
5. other indirect effects on fish behaviour caused by risk of seal predation.

This was the second of two workshops and presentations focused on new analyses and model results arising from research identified at the first workshop. The principal objective of these workshops was to review what is known, identify gaps in our understanding, and determine what could be concluded about the impacts of seals on fish stocks in eastern Canada. BIO Scientists presented five papers at the workshop. A report of the meeting will be completed early in 2009.

An information and exchange workshop, **Ocean Climate Variability in the Labrador Sea and Larger-Scale Linkages**, was hosted by BIO November 10-11, with over 30 participants from six countries. The workshop was convened by the Ocean Sciences Division (on behalf of DFO) and the US National Oceanic and Atmospheric Administration. Discussions focused on recent scientific results, current and planned programs, and future priorities for research on ocean climate variability, change, and ecosystem implications in the Labrador Sea region, as an important part of the North Atlantic and global climate system. There was consensus that there is a need to expand ocean climate observation programs in the region because of their importance to the Atlantic Meridional Overturning Circulation and in linking Arctic outflows to the North Atlantic.

The sixth meeting of the **Scientific Steering Group of the International Arctic-SubArctic Ocean Fluxes (ASOF) Study** was held at BIO on November 12-14. The meeting was hosted by DFO's Ocean Sciences Division. Forty-two participants from nine countries attended. The meeting included a one-day open session with presentations by BIO and other scientists whose research links with the present goals of ASOF, i.e., measuring and modelling the freshwater, heat, and mass fluxes leaving the Arctic Ocean. The aims of Phase II of ASOF were discussed during the second and third days of the meeting and these included maintaining the monitoring of the fluxes at strategic locations (gateways), increasing the modelling effort and the comparison to all ASOF observations, including the biological and chemical observations on ASOF-led surveys to understand the pathways and origins of the water masses, and fostering closer ties between the ASOF physics research and the marine ecosystem research being done under ESSAS.

On November 19-20, BIO hosted **a stakeholder workshop for the Offshore Environmental Factors and Marine Transportation Safety subprograms of the federal Program on Energy Research and Development**. The purpose of the workshop was twofold: 1) to communicate research and development results directly to those with a particular interest in offshore oil and gas issues on Canada's east coast and in the Arctic, and 2) for project and program leaders to receive feedback from stakeholders and colleagues. The program covered a wide range of topics from wind, wave, and sea-ice hazards, and mitigation of their impacts, to seafloor mapping and assessments of seabed stability. The primary outcomes of the meeting included a reconfirmation of a suite of stakeholder priorities with respect to offshore factors and transportation safety, as well as enthusiastic support for some new initiatives, such as underwater monitoring with autonomous vehicles (e.g., ocean gliders).

The **4th Eastern Scotian Shelf Integrated Management (ESSIM) Forum** was held November 25-26 at Pier 21 in Halifax, Nova Scotia. The workshop was co-hosted by the Oceans and Coastal Management Division, DFO Maritimes Region and the ESSIM Stakeholder Advisory Council. One of the primary aims of the workshop was to identify the way forward and to focus on implementation of the ESSIM plan that was released in June 2008.

The workshop featured sessions on the following topics:

- Marine spatial planning best practices and approaches
- Perspectives on integrated coastal management in Nova Scotia
- Linkages between Sable Island and the ESSIM plan
- Linkages between integrated ocean and coastal management and environmental assessment
- Case studies and experiences from other integrated management efforts
- Marine Protected Area network planning
- Information and mapping in support of integrated ocean and coastal management
- Priorities and opportunities for implementation of the ESSIM plan

The workshop was attended by approximately 165 people, representing different federal and provincial government departments, aboriginal organizations, marine industries, conservation interests, academia, and coastal communities.

Seminars 2008

Over the course of the year, BIO welcomed scientists from around the world to present seminars and to lecture at the Institute.

CENTRE FOR MARINE BIODIVERSITY (CMB) SEMINARS

The Centre for Marine Biodiversity invites scientists whose research in fisheries, marine ecology, physical oceanography, and related sciences will enhance our knowledge toward the protection of marine biodiversity.

A Fuzzy Characterization of Nova Scotia's Atlantic Inlets
Michelle Greenlaw, Geomatics Research Associate, CMB and M.Sc. Candidate, Acadia University, Wolfville, Nova Scotia, Canada

The Otter, the Mayor and the Billionaire: How They Brought Monterey Bay back to Life
Dr. Stephen Palumbi, Harold A. Miller Professor of Marine Sciences and Director, Hopkins Marine Station, Department of Biology, Pacific Grove, California, United States

HARVEST FISHERIES SEMINAR SERIES

The Harvest Fisheries Seminar Series began in 2002. Hosted by the Population Ecology Division, the primary purpose is to provide an opportunity to exchange ideas and to hear about research within BIO and at other institutions. Staff who will be speaking outside BIO are encouraged to also give their presentations at the Institute. As well, the program features visiting researchers and speakers from local universities.

Ecosystem Change in the Southern Gulf of St. Lawrence: Contrasting Changes in Natural Mortality between Size Classes in the Fish Community
Doug Swain, Gulf Fisheries Centre, DFO, Moncton, New Brunswick, Canada

Data Assimilation for Ecosystem Models using State Space Models
Mike Dowd, Department of Mathematics and Statistics, Dalhousie University, Halifax, Nova Scotia, Canada

A Temperature-Corrected Crustacean Abundance Index Obtained from Low Effort Sampling
Jacques Allard, Department of Mathematics and Statistics, Université de Moncton, Moncton, New Brunswick, Canada

Evolution of Lake Trout Morphs in the Canadian Arctic
Craig Blackie, Department of Biology, Dalhousie University

Survival Variability and Population Density: A Meta-analytical Approach
Coilin Minto, Department of Biology, Dalhousie University

Which Demographic Traits Determine Invasiveness in Marine Algae?
Rui Santos, University of the Algarve, Faro, Portugal

The Application of Spatial-Decision Support Tools in the Southern Strait of Georgia and Gwaii Haanas National Marine Conservation Areas
Krista Royle, Parks Canada, Vancouver, British Columbia, Canada

Large-scale Movement and Habitat Use Patterns of White Sharks (Carcharodon carcharias) in the New Zealand Region and Beyond: Trans-Oceanic Movements on an Annual Time Scale Seems to be the Rule rather than the Exception
Michael J. Manning, National Institute of Water and Atmospheric Research, Auckland, New Zealand

Temperature and the Distribution of Marine Vertebrates in the Northwest Atlantic and the World: A New Hypothesis
David Cairns, DFO, Charlottetown, Prince Edward Island, Canada

Statistical Inference for Food Webs, Part I: Bayesian Melding
Dr Grace Chiu, Department of Statistics and Actuarial Science, University of Waterloo, Waterloo, Ontario, Canada

A Country Whale in an Urban Ocean: The North Atlantic Right Whale Hangs in the Balance
Moe Brown, Scientific advisor for the Canadian Whale Institute, Bolton, Ontario, and a senior scientist in the Edgerton Research Laboratory at the New England Aquarium, Boston, Massachusetts, United States

Representative Coastal Inlet Classification and Gap Analysis
Michelle Greenlaw, Acadia University and St. Andrews Biological Station

OCEANS AND ECOSYSTEM SCIENCE SEMINAR SERIES

The Oceans and Ecosystem Science Seminar Series talks are given weekly and cover topics in physical, chemical, and biological oceanography. The series, run jointly by DFO's Ocean Sciences and Ecosystem Research divisions, provided a forum for both BIO researchers and the following visiting scientists in 2008:

Challenges in Ocean Modelling with Focus on the Nordic Seas
Jarle Berntsen, University of Bergen, Bergen, Norway

Broadband Scattering from Underwater Targets: Modelling and Classification
John Fawcett, Defence Research and Development Canada (Atlantic), Dartmouth, Nova Scotia, Canada

AZMP (Atlantic Zone Monitoring Program) and MetOc (Meteorology and Oceanographic) Ocean Products
Wayne Renaud, METOC, Department of National Defence, Halifax, Nova Scotia, Canada

Comparing Ecosystem Dynamics in Wet and Dry Places
Jonathan Shurin, Department of Zoology, University of British Columbia, Vancouver, British Columbia, Canada

Grazing Control of Plankton Dynamics: The Roles of Satiation, Food Limitation And Acclimation
Wendy Gentleman, Department of Engineering Mathematics and Internetworking, Dalhousie University

Development of a Biological-Physical Model Appropriate for Prediction in a Coastal Inlet
Maud Guarracino, Department of Oceanography, Dalhousie University

Impact of Anomalous Surface Forcing on the Sub-polar North Atlantic: Water Mass Formation and Circulation
Duo Yang, Department of Oceanography, Dalhousie University

Development of a New Ocean Reanalysis for the Reconstruction of Water Mass Variability and Climate Signals
Greg Smith, Environmental Systems Science Centre, University of Reading, Reading, United Kingdom

Multiplexing Video/Data Signals over Fibre Optics for Sub-sea Applications
Ian MacKay, Focal Technologies, Dartmouth, Nova Scotia, Canada

Assessing Environmental Risk of Ocean Fertilization for Carbon Sequestration
John J. Cullen, Department of Oceanography, Dalhousie University

Disentangling Variation in Fish Growth: Evidence for Size-selection in Southern Gulf of St. Lawrence Cod (Gadus morhua)
Anna Neuheimer, Department of Oceanography, Dalhousie University

A View of the Oceans from Washington
Rear Admiral Dick West, U.S. Navy (ret), Washington, D.C., United States

A Contribution to the Problem of Coupling in the Midlatitudes: SST Analyses from Ships and Buoys
Rick Danielson, Department of Oceanography, Dalhousie University

Ocean Abyssal Mixing and the Meridional Overturning Cell
Eric Kunze, Canada Research Chair, School of Earth and Ocean Science, University of Victoria, Victoria, British Columbia, Canada

Coastal Forecast Modelling in Support of Canadian Naval Applications
Keith Thompson, Department of Oceanography, Dalhousie University and Lt(N) Darryl Williams MetOc, Department of National Defence, Halifax, Nova Scotia, Canada

Climatologies of the Arctic Archipelago
Jonathan Beaudoin, Ocean Mapping Group, University of New Brunswick, Fredericton, New Brunswick, Canada

OCEANS AND COASTAL MANAGEMENT SEMINAR

DFO's Oceans and Coastal Management Division in conjunction with the Marine Affairs Program, Dalhousie University, sponsored the seminar:

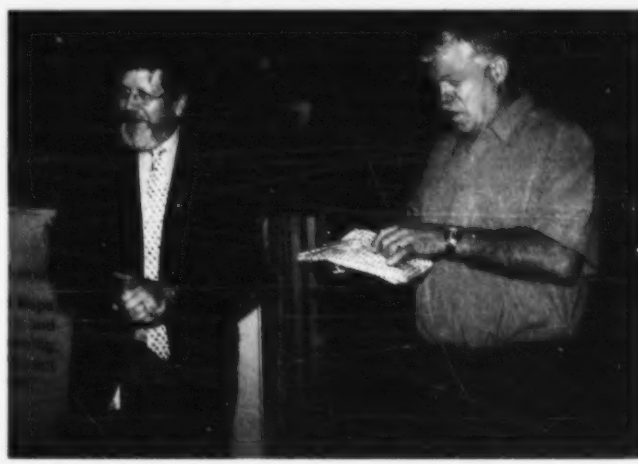
Implementing Integrated, Ecosystem-based Management through Marine Spatial Planning
Charles Ehler and **Fanny Douvere**, Consultants with UNESCO/Intergovernmental Oceanographic Commission, UNESCO Secretariat, Paris, France

For information on the UNESCO/IOC marine spatial management program, see (http://www.unesco-ioc-marinesp.be).

NRCAN SEMINAR

Prediction of Australia's Benthic Marine Habitat Diversity using Seascapes: A National Map
Dr. Scott Nicol, Petroleum Marine Division, Geoscience Australia, Canberra, Australia

Visitors and Special Events



Steve Forbes (left), Director of the CHS Atlantic, with Dick Pickrill, guest lecturer at the 2008 World Hydrography Day celebrations

Dr. Johann Sigurjonsson, the Director of the Marine Research Institute of Iceland, visited BIO on April 16. He was given a tour of the Institute, with a particular focus on the aggregate research and monitoring activities in support of fisheries. Ross Claytor of the Population Ecology Division provided information on a wide range of partnerships with different components of the fishing industry, including an overview of the Fishermen and Scientists Research Society.

DFO's Quebec and Maritimes regions co-hosted **a reception for the scientists from the French Research Institute for Exploitation**

From left: Andrew Bagnell (NS Department of Fisheries and Aquaculture), Melanie MacLean (OHSAR), and David Duggan (OHSAR)

From left: Diane Beanlands (OHSAR), David Jennings (DFO Communications), and Dawn Sephton, (OHSAR)

World Oceans Day - A Time to Remember the Life-Giving Role of Oceans

Oceans, Habitat and Species at Risk (OHSAR) Branch celebrated World Oceans Day 2008 on the Halifax waterfront. With partners, OHSAR hosted an educational event to remind people that the oceans power our climate, are a critical part of the biosphere, and are essential to food security and the health and survival of all life. World Oceans Day was declared at the UN Conference on Environment and Development in Rio de Janeiro in 1992; in 2008, the UN General Assembly formally designated June 8 as its date.

of the Seas (IFREMER), France who were participating in the annual science conference of the International Council for the Exploration of the Sea (ICES) held in Halifax, September 22-26. The goal of the event was to facilitate enhanced collaboration between DFO and IFREMER scientists on research activities in support of the ecosystem approach to management. The collaborative projects are to be reviewed during the DFO/IFREMER Committee Mixer in the spring of 2009.

The Canadian Hydrographic Service (CHS) Atlantic celebrated **World Hydrography Day** at BIO on June 20. The celebration began with a lecture by Dick Pickrill of NRCan titled *Charts and Maps, Hydrography, and Seafloor Mapping: The Past, Present, and Future*. The lecture was well attended and received. A reception with cake and coffee followed.

From left: Andrew Bagnell (NS Department of Fisheries and Aquaculture), Melanie MacLean (OHSAR), and David Duggan (OHSAR)

From left: Diane Beanlands (OHSAR), David Jennings (DFO Communications), and Dawn Sephton, (OHSAR)

World Oceans Day - A Time to Remember the Life-Giving Role of Oceans

Oceans, Habitat and Species at Risk (OHSAR) Branch celebrated World Oceans Day 2008 on the Halifax waterfront. With partners, OHSAR hosted an educational event to remind people that the oceans power our climate, are a critical part of the biosphere, and are essential to food security and the health and survival of all life. World Oceans Day was declared at the UN Conference on Environment and Development in Rio de Janeiro in 1992; in 2008, the UN General Assembly formally designated June 8 as its date.

of the Seas (IFREMER), France who were participating in the annual science conference of the International Council for the Exploration of the Sea (ICES) held in Halifax, September 22-26. The goal of the event was to facilitate enhanced collaboration between DFO and IFREMER scientists on research activities in support of the ecosystem approach to management. The collaborative projects are to be reviewed during the DFO/IFREMER Committee Mixer in the spring of 2009.

The Canadian Hydrographic Service (CHS) Atlantic celebrated **World Hydrography Day** at BIO on June 20. The celebration began with a lecture by Dick Pickrill of NRCan titled *Charts and Maps, Hydrography, and Seafloor Mapping: The Past, Present, and Future.* The lecture was well attended and received. A reception with cake and coffee followed.

Awards and Honours

Dr. Roger François, the 2008 A. G. Huntsman Award winner

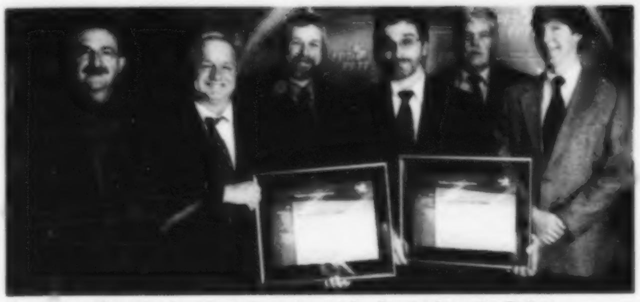
Wendy Watson-Wright, DFO Assistant Deputy Minister of Science, presents the Timothy R. Parsons Award to Don Gordon.

The **2008 A.G. Huntsman Award** was presented to **Dr. Roger François** for his groundbreaking research and leadership in marine geochemistry. Dr. François holds a Canada Research Chair in the Department of Earth and Ocean Sciences, University of British Columbia (UBC). He obtained his PhD from UBC in 1987 and spent the subsequent fifteen years at the Department of Marine Chemistry and Geochemistry at the Woods Hole Oceanographic Institution, where he is still an adjunct scientist. He has been actively involved in large international programs with a biogeochemical focus and is internationally renowned for his insightful research in marine biogeochemistry, his innovative skill in data acquisition and analysis, and his interpretation of the complex behaviour of the ocean–atmosphere system over long-term climatic timescales.

The A.G. Huntsman Award recognizes international scientists for research excellence and outstanding contributions and is presented annually in one of three categories: Marine Geosciences; Physical/Chemical Oceanography; or Biological Oceanography and Fisheries Sciences. The award was created in 1980 under the leadership of BIO scientists to honour the memory of Archibald G. Huntsman, a Canadian oceanographer and fishery biologist pioneer. The 2008 award was presented by Dr. Andrew Miall, President of the Academy of Sciences of the Royal Society of Canada, at a special ceremony at BIO on November 27.

Donald C. Gordon, BIO Scientist Emeritus, received the **Timothy R. Parsons Award for Excellence in Oceans Science** in a ceremony at BIO. The award recognizes a Canadian scientist with "distinguished accomplishments in multi-disciplinary facets of ocean sciences". Don received the award for "excellence during his lifetime" of 35 years' work in biological oceanography and marine ecology. His contributions have had an important impact on government policy and regulation, particularly with respect to the protection and ecosystem-based management of Canadian ocean resources. Moreover, the award honours his influence in motivating, mentoring, and providing leadership in the workplace. Accepting the award, Don gave a delightful summary of his research career at BIO, as well as acknowledgement of the collaborative nature of his achievements with staff at the Institute.

A team of BIO scientists received a **2008 Excellence in Technology Transfer Award, Federal Partners in Technology Transfer** (FPTT), for the successful development, transfer, and commercialization of multibeam sonar seafloor imaging applications for the fishing industry. Team Members from NRCan were **Robert Courtney, Vladimir Kostylev, Richard Pickrill, and Brian Todd**;



Technology Transfer Award winners, from left: Gerard Costello, Robert Courtney, Michael Lamplugh, Vladimir Kostylev, Richard Pickrill, and Brian Todd.

from DFO they were **Gerard Costello** and **Michael Lamplugh**. Charting the ocean floor with the thoroughness of a mapmaker on land, this environmentally conscious technology has rejuvenated a beleaguered fishing industry while protecting the underwater habitat that sustains it. BIO scientists developed unique software that converts existing multibeam sonar data into digital maps that capture the contours and detailed composition of seafloors. Traditional trawling practices of blindly dragging gear over large swathes of seafloor destroyed not only aquatic habitats but also expensive equipment. By discerning different surface textures such as sand or rocky outcrops, the software enables users to predict where different species are likely to be found. In turn, fishing fleets can efficiently target known habitats and sharply reduce operating costs and area of seafloor trawled. As a result of the new technology, a previously inaccessible fishery was opened off Nova Scotia in 2001, adding $29 million to the economy in the first five years. Reducing trawling by as much as 75 %, multibeam imaging is a powerful tool for conservation and seafloor management. FPTT is an established network of federal public servants committed to working together to enhance their professional capacity and to ensure the expeditious transfer of the value created in federal laboratories.

On October 29, friends and colleagues gathered in the BIO Library

Anna Fiander, Chief of Library Services, presents Dr. Mann with his name plaque, to be affixed to Library Carrel #1.

Beluga Award Winner, Borden Chapman

to honour Scientist Emeritus, **Dr. Ken Mann**. The event celebrated Dr. Mann's contributions to Science research (his books were on display), and his staunch use and support of the library during his working career. Library Carrel #1 in the library stacks has been named in his honour.

Borden Chapman received the BIO Oceans Association 2008 **Beluga Award** in recognition of his outstanding career of more than 30 years with NRCan's Geological Survey of Canada (Atlantic), formerly known as the Atlantic Geoscience Centre. His contributions ranged from mentoring young staff and students in electronic equipment operation, through key support of ocean-going expeditions, to the design of new data acquisition systems. He has exemplified the unselfish effort that encourages cooperation and fosters teamwork at BIO.

Michael Sinclair and **Thomas Sephton** received the **Ambassador Award** from **Destination Halifax** in appreciation of their efforts to promote Halifax as the host destination for the 2008 International Council for the Exploration of the Sea Annual Science Conference held at the Halifax World Trade and Convention Centre.

Natural Resources Canada Sector Merit Awards are awarded by the Earth Sciences Sector of NRCan to recognize the behaviours, actions, or results of an individual or team whose level of impact and scope has enhanced the profile and contributed to the success of the Earth Sciences Sector. In 2008, the following BIO staff received Merit Awards:

Steve Solomon, as a member of the "MacKenzie Gas Project Hearings: ESS Expert Witness" team;

Robbie Bennett and **Calvin Campbell**, for "Exceptional Leadership, for the Collaborative NRCan-University Expedition".

NRCan Long Service Awards were given to:

35 years	**Pat Dennis, Ruth Jackson, Bill LeBlanc, Bob Taylor**
25 years	**Nelly Koziel, Maureen MacDonald, Russell Parrott**
15 years	**Sonya Dehler, David Mosher, Richard Pickrill**

The **DFO Distinction Award** is granted to an employee for outstanding achievement and contributions that further the objectives of DFO and/or the Public Service of Canada. The award is based on excellence in service delivery; valuing and supporting people; and value, ethics, and excellence in policy and/or science. The most exemplary contributions to DFO are honoured with the **Deputy Minister's (DM's) Prix d'Excellence**.

Allyn Clarke, Trevor Platt, and **Igor Yashayaev** of the Ocean Sciences Division were among thirteen DFO scientists who received the **DFO Science Distinction Award** and the **DM's Prix d'Excellence** for their work with the Intergovernmental Panel on Climate Change (IPCC). The IPCC was a joint recipient (with former US Vice-President Al Gore) of the 2007 Nobel Peace Prize for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change.

DM's Prix d'Excellence ceremony, from left, Igor Yashayaev; Wendy Watson-Wright, who presented the award; Trevor Platt; and Allyn Clarke

2008 Distinction Awards:

Gary Bugden (Ocean Sciences) has demonstrated long-term and exemplary leadership in the area of nearshore oceanographic research, to address regional and national issues. Particularly, he has been responsible for making "Puddleography" (concerning water you can stand up in) one of the most successful areas of research at BIO, and has served as a model for how to conduct and explain research that directly addresses societal needs.

Steven Campana (Population Ecology), Media Spokesperson of the Year, has been a tremendous ambassador for science, demonstrating extraordinary skills to promote scientific research to the media and the public.

Danielle MacDonald, (Population Ecology, Mactaquac Biodiversity Facility) has made a valuable contribution to excellence in service delivery throughout her career in Science, and in particular, showed true leadership and commitment before, during, and after the flooding of the Mactaquac Biodiversity Facility.

Julie LeClerc, Judy Simms, Steven Fancy, Mylène DiPenta, and **Wendy Woodford** received the Maritimes Region Diversity Distinction Award for their excellent volunteer, cross-sectoral work with the Outreach Project. Their positive workplace practices have fostered a corporate culture that supports diversity, resulting in an exceptional move forward for the region and DFO towards its employment equity goals. Nationally, this is the first team to take a coordinated approach to outreach and employment equity activities.

DFO Distinction Awards 2007 (awarded in 2008):

Oceans, Habitat and Species at Risk

Darria Langill demonstrated excellence in service delivery by working with the Province of Nova Scotia to ensure that DFO's National Operating Statements are consistent with, and supportive of, provincial policies and practices for aquatic environments. She was recognized also for working tirelessly on overseeing the production of the plain-language (in English and French) East Coast Reader which described the fish habitat program in New Brunswick.

Anita Hamilton, Jim Leadbetter, and **Stacey Nurse** of the **Salt Marsh Team** worked with outside partners to find an acceptable compensation project for Harmful Alteration, Disruption or Destruction of fish habitat from road construction on the twinning of Highway 103. Overcoming many policy and logistical problems, the team was successful in the restoration of the salt marsh on Cheverie Creek, forging the trail to establish the processes for the effective and efficient regulatory reviews of numerous public infrastructure projects in Nova Scotia while at the same time securing the restoration of a number of salt marshes.

David Duggan and **Stan Johnston** were on the intergovernmental **Musquash Marine Protected Area (MPA) Implementation Team** who worked together beyond normal expectations to bring about the MPA designation, resulting in the long-term protection of this important coastal area. The team's visionary approach to shared Federal-Provincial responsibility is an excellent example of governments working together in the public interest.

Science

Carolyn Harvie (Population Ecology) has been instrumental in developing and implementing innovative solutions that significantly improved delivery of the Region's inner Bay of Fundy Live Gene Bank program and Species-at-Risk program for the recovery of Atlantic salmon.

Ellen Kenchington (Ecosystem Research) received the Communications Distinction Award for the Maritimes Region Media Spokesperson of the Year for excellence in dealing with local, regional, national, and international media, explaining complex scientific missions with enthusiasm and skill.

Carolyn Harvie (left) was presented with the DFO Distinction Award by Faith Scattolon, Regional Director-General, and Michael Sinclair, Director of Science.

The BIO Open House Team received the DFO Distinction Award for their stellar organization and successful execution of the 2007 BIO Open House. More than 20,000 people including busloads of school children attended the five-day event which celebrated BIO's 45th birthday by showcasing BIO science in 66 exhibits and two days of presentations. The Open House Team: from left, front: Jennifer Hackett, Carl Myers, Francis Kelly, Claudia Currie, Mike Lamplugh, Brian Todd; back, Mike Sinclair, René Lavoie, Sheila Shellnut, Ken Asprey, Bill Bewsher, Maureen MacDonald, and Bruce Anderson; and Faith Scattolon (who presented the award).

John Loder (Ocean Sciences) demonstrates exemplary leadership, selfless dedication, and excellent management as Head of the Ocean Circulation Section. In particular, he was recognized for his communication and support of staff within the section, cross-sectoral coordination of field work and research, excellence in science with responsible use of resources and maximum program outputs, and for his role in establishing and directing the Centre of Expertise for Ocean Model Development and Application.

Phillip MacAulay (Canadian Hydrographic Service) and **Kohila Thana** (Ocean Sciences) were recognized for the timely development of the **Real Time Water Level System** for the new Atlantic Tsunami/Storm Surge Warning System. Phil's oceanographic and mechanical engineering background was a major asset in designing a pragmatic operational system for water level data collection and quality control, utilizing modern scientific and information technology advances. Kohila was responsible for the development and implementation of all IT aspects of the project, which included the real-time water level database and Emergency Measures webpage.

By combining his designer, fabricator, and machinist skills with a positive attitude, **Glen Morton** (Ocean Sciences) has been responsible for inventing new ways to investigate the complex ocean environment, in particular instrumentation packages that have been at the core of essential research projects related to offshore oil and gas, trawling impacts, and investigation of The Gully Marine Protected Area.

In 2006 a legal decision known as the Larocque decision changed the way that industry was permitted to support DFO science projects. Population Ecology's **Ross Claytor**, **Jim McMillan**, and **Catherine Wentzell** with **Debbie Murphy** of Fisheries and Aquacutlure Management were members of the **Fisheries and Aquaculture Management/Larocque Implementation Team** which organized the response to Legal Services on behalf of Maritimes Region and so ensured a consistent approach to projects within a risk management framework. There has been widespread support for this approach.

35-year Service Recognition:

Sandra Gallagher
Janet Gilbey (awarded in 2007)
Trevor Goff
Marilyn Landry
James Leadbetter

Bedford Institute of Oceanography Oceans Association: Activities in 2008

Robert O'Boyle

The Bedford Institute of Oceanography Oceans Association (BIO-OA) was established ten years ago by a group of former staff to foster the continuing fellowship of members, which now number more than 250, and to maintain links to the Institute. The OA's mandate includes increasing public understanding of oceans science and the preservation of the Institute's history and spirit.

During 2008, much work was devoted to preserving BIO history. One of the most prominent endeavours is the Commemorative Stamp Project, a proposal to have Canada Post issue a stamp in 2012, the 50th Anniversary of the founding of BIO. A significant part of the submission is a history of the Institute's contributions to ocean science, both in Canada and internationally.

Another history project aims to document the role of the HMCS *Sackville* in ocean-going research in the early days of the 20th Century. The *Sackville* is on display on the Halifax waterfront; this project will help ensure that its proper historical place in Canadian ocean research is better known and communicated.

Over the years, BIO has developed a wide array of ocean

Carolyn Harvie (left) was presented with the DFO Distinction Award by Faith Scattolon, Regional Director-General, and Michael Sinclair, Director of Science.

The BIO Open House Team received the DFO Distinction Award for their stellar organization and successful execution of the 2007 BIO Open House. More than 20,000 people including busloads of school children attended the five-day event which celebrated BIO's 45th birthday by showcasing BIO science in 66 exhibits and two days of presentations. The Open House Team: from left, front: Jennifer Hackett, Carl Myers, Francis Kelly, Claudia Currie, Mike Lamplugh, Brian Todd; back: Mike Sinclair, René Lavoie, Sheila Shellnut, Ken Asprey, Bill Bewsher, Maureen MacDonald, and Bruce Anderson; and Faith Scattolon (who presented the award).

John Loder (Ocean Sciences) demonstrates exemplary leadership, selfless dedication, and excellent management as Head of the Ocean Circulation Section. In particular, he was recognized for his communication and support of staff within the section, cross-sectoral coordination of field work and research, excellence in science with responsible use of resources and maximum program outputs, and for his role in establishing and directing the Centre of Expertise for Ocean Model Development and Application.

Phillip MacAulay (Canadian Hydrographic Service) and **Kohila Thana** (Ocean Sciences) were recognized for the timely development of the **Real Time Water Level System** for the new Atlantic Tsunami/Storm Surge Warning System. Phil's oceanographic and mechanical engineering background was a major asset in designing a pragmatic operational system for water level data collection and quality control, utilizing modern scientific and information technology advances. Kohila was responsible for the development and implementation of all IT aspects of the project, which included the real-time water level database and Emergency Measures webpage.

By combining his designer, fabricator, and machinist skills with a positive attitude, **Glen Morton** (Ocean Sciences) has been responsible for inventing new ways to investigate the complex ocean environment, in particular instrumentation packages that have been at the core of essential research projects related to offshore oil and gas, trawling impacts, and investigation of The Gully Marine Protected Area.

In 2006 a legal decision known as the Larocque decision changed the way that industry was permitted to support DFO science projects. Population Ecology's **Ross Claytor**, **Jim McMillan**, and **Catherine Wentzell** with **Debbie Murphy** of Fisheries and Aquaculture Management were members of the **Fisheries and Aquaculture Management/Larocque Implementation Team** which organized the response to Legal Services on behalf of Maritimes Region and so ensured a consistent approach to projects within a risk management framework. There has been widespread support for this approach.

35-year Service Recognition:

Sandra Gallagher
Janet Gilbey (awarded in 2007)
Trevor Goff
Marilyn Landry
James Leadbetter

Bedford Institute of Oceanography Oceans Association: Activities in 2008

Robert O'Boyle

The Bedford Institute of Oceanography Oceans Association (BIO-OA) was established ten years ago by a group of former staff to foster the continuing fellowship of members, which now number more than 250, and to maintain links to the Institute. The OA's mandate includes increasing public understanding of oceans science and the preservation of the Institute's history and spirit.

During 2008, much work was devoted to preserving BIO history. One of the most prominent endeavours is the Commemorative Stamp Project, a proposal to have Canada Post issue a stamp in 2012, the 50th Anniversary of the founding of BIO. A significant part of the submission is a history of the Institute's contributions to ocean science, both in Canada and internationally.

Another history project aims to document the role of the HMCS *Sackville* in ocean-going research in the early days of the 20th Century. The *Sackville* is on display on the Halifax waterfront; this project will help ensure that its proper historical place in Canadian ocean research is better known and communicated.

Over the years, BIO has developed a wide array of ocean

This photo from the BIO Library's photo archives was taken in the early 1980s, and shows, from left: Donald Tansley, a past Deputy Minister of DFO; Captain Fred Mauger, then Master of the CSS Hudson; and James (Jim) Rippey, Chief Engineer on the Hudson. Photo was taken by The Chronicle Herald.

sampling equipment—BATFISH, BIONESS, DOLPHIN, CAMPOD, to name a very few—to meet the demanding and unique needs of its many ocean survey activities. The right equipment cannot be found in a hardware store. The gear has to be conceived, designed, built, tested, perfected, and ultimately deployed, all of which the Institute has been very successful in undertaking. Indeed, some BIO equipment has been transferred to the private sector and commercially marketed, nationally and internationally. The OA continues to be active in ensuring that examples of this equipment are archived for posterity.

Oceans outreach is the second key element of the Association's mandate. Over the years, the Institute has had an active outreach program with a successful summer tour program and well attended Open Houses every 5 years. The OA has collaborated in these efforts with its own activities and is currently working on a collaborative outreach plan with the Institute.

Probably the most active area of the Association's mandate has been fostering communication among past and present BIO members. This is achieved through a number of activities, including social events and specially scheduled science talks. The Association's newsletter, a quarterly publication, keeps the membership abreast of oceans affairs within and outside BIO. Since October 2002, the *Noteworthy Reads* column has provided members with over 300 reviews of books on the marine sciences and other marine subjects. The BIO Oceans Association website is another important communication vehicle.

Finally, the Association has been active in highlighting the outstanding contributions of members. The Association sponsors the Beluga Award, given annually to a BIO staff member who exemplifies the ethos embodied by the Association. In 2008, Borden Chapman received the award for his outstanding career of over 30 years at BIO. (See Awards and Honours.)

Charitable Activites at BIO

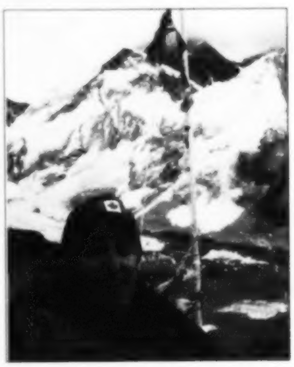
In 2008, BIO staff continued their long tradition of giving back to their community.

The Government of Canada Workplace Charitable Campaign (GCWCC) is the oldest and largest workplace charitable campaign in Canada. Approximately 50 local agencies benefit from this campaign, which brings together two main recipient organizations—United Way and Healthpartners—in a co-ordinated fundraising effort. Alternatively, employees can give to a third option, their Charity of Choice(s). Both DFO and NRCan employees gave generously this year by individual pledges, and also through several fundraising events, including the Christmas Hockey Game/Family Skate and Dance, a baseball game, and participation in local federal government fund-raising events. A particular favourite with staff is the annual used book sale put on by BIO Library staff, which, in 2008, raised its largest amount yet.

As in previous years, NRCan was instrumental in organizing BIO staff to pack and deliver Christmas dinners for the Parker Street Food and Furniture Bank. As part of that support, the rental fees for four large delivery vehicles were paid from the Christmas event. BIO further supports this food bank throughout the year with donations of food and clothing.

The Canadian Hydrographic Service provided several gift-filled boxes for the Halifax Mission to Seamen's Christmas Appeal, when the Mission gives Christmas Shoe Boxes of Gifts to seafarers visiting the port over the holidays. A box typically contains a warm hat, scarf, socks, toiletries, and candy. In further charitable activity, the DFO Ecosystem Research Division continued its practice of helping needy families at Christmas by holding Easter and Hallowe'en coffee

Everest Base Camp and Kala Patthar Charity Climb for Feed Nova Scotia



Several BIO employees pledged support to their colleague, Darrell Harris, as he raised $4,583 for Feed Nova Scotia through his "self-directed" climb to the Mount Everest Base Camp in Nepal at 17,600 feet and the summit of nearby Kala Patthar at 18,515 feet. Darrell joined 12 other international climbers in his second ascent for Feed Nova Scotia. As in his 2006 Kilimanjaro climb, Darrell found this an extremely cold, windy, and oxygen-deprived environment but had an overall excellent experience with continual spectacular scenery and an exciting flight into Lukla, an airstrip literally up the side of a mountain at 9,380 feet altitude. Darrell covered the costs of the trip to Nepal himself.

This photo from the BIO Library's photo archives was taken in the early 1980s, and shows, from left: Donald Tansley, a past Deputy Minister of DFO; Captain Fred Mauger, then Master of the CSS Hudson; and James (Jim) Rippey, Chief Engineer on the Hudson. Photo was taken by The Chronicle Herald.

sampling equipment—BATFISH, BIONESS, DOLPHIN, CAMPOD, to name a very few—to meet the demanding and unique needs of its many ocean survey activities. The right equipment cannot be found in a hardware store. The gear has to be conceived, designed, built, tested, perfected, and ultimately deployed, all of which the Institute has been very successful in undertaking. Indeed, some BIO equipment has been transferred to the private sector and commercially marketed, nationally and internationally. The OA continues to be active in ensuring that examples of this equipment are archived for posterity.

Oceans outreach is the second key element of the Association's mandate. Over the years, the Institute has had an active outreach program with a successful summer tour program and well attended Open Houses every 5 years. The OA has collaborated in these efforts with its own activities and is currently working on a collaborative outreach plan with the Institute.

Probably the most active area of the Association's mandate has been fostering communication among past and present BIO members. This is achieved through a number of activities, including social events and specially scheduled science talks. The Association's newsletter, a quarterly publication, keeps the membership abreast of oceans affairs within and outside BIO. Since October 2002, the *Noteworthy Reads* column has provided members with over 300 reviews of books on the marine sciences and other marine subjects. The BIO Oceans Association website is another important communication vehicle.

Finally, the Association has been active in highlighting the outstanding contributions of members. The Association sponsors the Beluga Award, given annually to a BIO staff member who exemplifies the ethos embodied by the Association. In 2008, Borden Chapman received the award for his outstanding career of over 30 years at BIO. (See Awards and Honours.)

Charitable Activites at BIO

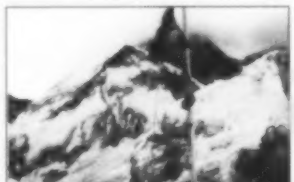
In 2008, BIO staff continued their long tradition of giving back to their community.

The Government of Canada Workplace Charitable Campaign (GCWCC) is the oldest and largest workplace charitable campaign in Canada. Approximately 50 local agencies benefit from this campaign, which brings together two main recipient organizations—United Way and Healthpartners—in a co-ordinated fundraising effort. Alternatively, employees can give to a third option, their Charity of Choice(s). Both DFO and NRCan employees gave generously this year by individual pledges, and also through several fundraising events, including the Christmas Hockey Game/Family Skate and Dance, a baseball game, and participation in local federal government fund-raising events. A particular favourite with staff is the annual used book sale put on by BIO Library staff, which, in 2008, raised its largest amount yet.

As in previous years, NRCan was instrumental in organizing BIO staff to pack and deliver Christmas dinners for the Parker Street Food and Furniture Bank. As part of that support, the rental fees for four large delivery vehicles were paid from the Christmas event. BIO further supports this food bank throughout the year with donations of food and clothing.

The Canadian Hydrographic Service provided several gift-filled boxes for the Halifax Mission to Seamen's Christmas Appeal, when the Mission gives Christmas Shoe Boxes of Gifts to seafarers visiting the port over the holidays. A box typically contains a warm hat, scarf, socks, toiletries, and candy. In further charitable activity, the DFO Ecosystem Research Division continued its practice of helping needy families at Christmas by holding Easter and Hallowe'en coffee

Everest Base Camp and Kala Patthar Charity Climb for Feed Nova Scotia



Several BIO employees pledged support to their colleague, Darrell Harris, as he raised $4,583 for Feed Nova Scotia through his "self-directed" climb to the Mount Everest Base Camp in Nepal at 17,600 feet and the summit of nearby Kala Patthar at 18,515 feet. Darrell joined 12 other international climbers in his second ascent for Feed Nova Scotia. As in his 2006 Kilimanjaro climb, Darrell found this an extremely cold, windy, and oxygen-deprived environment but had an overall excellent experience with continual spectacular scenery and an exciting flight into Lukla, an airstrip literally up the side of a mountain at 9,380 feet altitude. Darrell covered the costs of the trip to Nepal himself.

parties and selling tickets on gift baskets and artistically carved pumpkins; *BIO Friends of Symphony Nova Scotia* again supported the symphony's Celebrity Concert Series through the BIO Musical Chair of viola musician, Binnie Brennan; the Canadian Cancer Society's annual daffodil campaign was well subscribed; and other charities were helped on an occasional basis.

A Visit to Sable Island

Marilynn Rudi

I was the lucky winner of the GCWCC draw for a trip to Sable Island, Nova Scotia, an island in the Atlantic Ocean 300 km east of Halifax. The excursion, organized as part of the Canadian Coast Guard's annual supply of Sable Island, consisted of a helicopter flight to the island, a guided tour by Gerry Forbes, Head of the Sable Island Station, lunch and dinner onboard the CCGS *Sir William Alexander*, and an afternoon to wander the dunes.

The excitement started the morning of May 29 at the CCG hangar at Shearwater airport where I met fellow passengers and our helicopter pilot, Paul Mosher. I felt very smart and aeronautic decked out in an orange survival suit for the flight which took 90 minutes. It was fascinating to spot fishing ships and tankers way down below.

Ready to embark for Sable Island are DFO employees Theresa MacDonald, David Beaver, and Marilynn Rudi (right.)

Marilynn Rudi amid the dunes of Sable Island, with BIO House in the background

We were about 160 km from the coast of Nova Scotia when Sable Island appeared on the horizon at a congruence of currents. This is where the Gulf Stream and the Labrador Current meet. Soon we could see a sliver of silver in the water which otherwise looked surprisingly Caribbean blue. Flying over the island, we saw hundreds of seals in the water and sunning themselves on the beach. We were thrilled to see small bands of horses scattered across the island.

Upon landing, we were greeted by Jim McMillan of DFO Science at BIO and Gerry Forbes of Environment Canada. Gerry gave us a tour of the island, along Wallace Lake and out to the "airport", passing hundreds of grey and harbour seals, an Arctic tern colony, and horses of all sizes and colours. After the drive he led a walkabout of the Sable Island Station where an amazing array of scientific data is collected: meteorological, climatological, geomagnetic, and seismic.

For lunch we were flown by helicopter to the CCGS vessel *Sir William Alexander* which was anchored offshore. (Landing on a ship was a novel experience.) After lunch in the Officers' Mess, we were given a tour of the ship's bridge.

We spent the afternoon on foot in search of wild horses. Spotting a band on the beach, we made our way across the dunes. The stallion came trotting down the beach to check us out, then we accompanied him to where his herd was grazing on the stubby beach grass. We sat down; the horses completely ignored us as they grazed among us. We were tickled to see a very young foal among the group.

After a delicious dinner on board ship, we climbed back into our survival suits for the return journey to the mainland, arriving at Shearwater just as the sun was beginning to set. This trip was an experience I'll never forget, and the best ten dollars I have ever spent!!

People at BIO in 2008

DEPARTMENT OF NATIONAL DEFENCE

LCdr Jim Bradford
Lt(N) Jason Karle
CPO2 Doug Brown
PO2 Tim Craig
PO2 Ryan Gaudet
PO2 Marilyn Gilby
PO2 Jim McNeill
PO2 Emile Roussy
MS Gerard Arsenault
LS William Brown
LS Chris Dorion
LS Harris Pollard
Dan Moore

ENVIRONMENT CANADA

Christopher Craig
Patti Densmore
David MacArthur
Lauren Steeves

FISHERIES AND OCEANS CANADA

Canadian Coast Guard - Technical Services

Marine Electronics
Jim Wilson, Supervisor
Robert MacGregor, A/Supervisor
Terry Cormier
Gerry Dease
Jason Green
Julie LeClerc
David Levy
Robert MacGregor
Richard Malin
Mike O'Rourke*
Phil Pidgeon
Morley Wright

Vessel Support
Dan Chipman, Supervisor
Steve Christian
Paul Crews
Richard LaPierre
Ensor MacNevin
André McDonald
Stan Myers
Steve Myers
Lloyd Oickle
Harvey Ross
David Usher

Marine and Civil Infrastructure
Martin LaFitte
Leonard Mombourquette
Richard Myers
Raymond Smith

SIGMA-T Crew
Kirby Fraser
Charles Hamilton

Dartmouth Technical Workshop
Paul McKiel, Supervisor
Lorne Anderson
Bob Brown
Maurice Doucet
Peter Ellis
Milo Ewing
Tim Hooper
Andrew Hughes
Heather Kinrade
Susan Kolesar
Katie LaFitte
Chad Maskine
Andrew Morrison
Doug Murray
Derek Oakley
Helmut Samland
Mike Szucs
Phil Veinot

Science Branch

Regional Director's Office
Michael Sinclair, Director
Karen Curlett
Charlene Mathieu
Sharon Morgan
Sherry Niven
Bettyann Power
Heather Smith

Canadian Hydrographic Service (Atlantic)
Steve Forbes, Director, Hydrography Atlantic
Richard MacDougall, Director UNCLOS
Bruce Anderson
Carol Beals
Frank Burgess
Fred Carmichael
Lynn Collier
Mike Collins
Chris Coolen
Jacinthe Cormier
Gerard Costello
Andy Craft
Elizabeth Crux*
John Cunningham
Tammy Doyle
Theresa Dugas
Chris Eastman
Jon Griffin
Judy Hammond
James Hanway
Heather Joyce
Glen King
Mike Lamplugh
Christopher LeBlanc
Philip MacAulay
Bruce MacGowan
Carrie MacIsaac
Clare McCarthy
Dave McCarthy
Michael McMahon
Mark McCracken
Michael Nickerson
Larry Norton
Stephen Nunn
Charlie O'Reilly
Nick Palmer
Richard Palmer*
Paul Parks
Stephen Parsons
Bob Pietrzak
Sara Rahr
Doug Regular
Glenn Rodger
Dave Roop
Tom Rowsell
Chris Rozon

Term and casual employees, interns, students, and contractors are listed if they worked at BIO for at least four months in the year 2008.
* Retired in 2008 ** Deceased in 2008

Mike Ruxton
Kelly Sabadash
June Senay
Alan Smith*
Andrew Smith
Christian Solomon
Michel Therrien
Herman Varma
Tammy Waltcher
Wendy Woodford
Craig Wright
Craig Zeller

Ecosystem Research Division
Alain Vézina, Manager
Debbie Anderson
Sheila Shellnutt
Judy Simms

Centre for Offshore Oil and Gas Environmental Research (COOGER):
Kenneth Lee, Executive Director
Dan Belliveau, Student
Jay Bugden
Susan Cobanli
Jennifer Dixon
Roderick Doane
Paul Kepkay
Thomas King
Zhengkai Li
Haibo Niu, Postdoctoral fellow
Brian Robinson
Peter Thamer

Habitat Ecology Section:
Eddy Kennedy, A/Head
Brian Amirault
Anne Aubut, Student
Daniel Beach, Student
Lindsay Beazley
Robert Benjamin
Megan Best
Cynthia Bourbonnais-Boyce*
Monica Bravo, Student
Chiu Chou
Pierre Clement
Andrew Cogswell
Peter Cranford
Claudio DiBacco
Kristin Dinning, Student
Candice Eastwood, Student
Sarah Erskine, Student
Deanna Ferguson
Jennifer FitzGerald
Jennifer Harris
Jocelyne Hellou
Donald Humphrey, Student
Joanne Keays
Ellen Kenchington
Brent Law
Tina Lum, Student
Barry MacDonald
Kevin MacIsaac
Paul MacPherson
Jean Marc Nicolas
Vanessa Page, Student
Lisa Paon
Shawn Roach
Leslie Saunders, Student
Dawn Sephton
Saima Sidik
Sean Steller
Bénédikte Vercaemer
Jaime Vickers
Melisa Wong
Kees Zwanenburg

Ocean Research and Monitoring Section:
Glen Harrison, Head
Jeffrey Anning
Carol Anstey
Oliver Berreville, Student
Benoit Casault
Carla Caverhill
Grazyna Folwarczna
Leslie Harris
Erica Head
Diane Horn
Edward Horne
Catherine Johnson
Mary Kennedy
Marilyn Landry
William Li
Alan Longhurst, Visiting Scientist
Heidi Maass
Richard Nelson
Ashley Parson, Student
Kevin Pauley
Tim Perry
Catherine Porter
John Smith
Jeffrey Spry
Phil Yeats*

Centre for Marine Biodiversity:
Victoria Clayton

POGO Secretariat:
Shubha Sathyendranath, Executive Director
Marie-Hélène Forget

Ocean Sciences Division
Michel Mitchell, Manager
Sharon Gillam-Locke
Gabriela Gruber

Coastal Ocean Science:
Simon Prinsenberg, Head
Dave Brickman
Gary Bugden
Sandy Burtch
Jason Chaffey
Joël Chassé
Kate Collins
Brendan DeTracey
Adam Drozdowski
Jonathan Fisher, Postdoctoral Fellow
Ken Frank
Dave Greenberg
Charles Hannah
Ingrid Peterson
Brian Petrie
Liam Petrie
Roger Pettipas
Trevor Platt
Peter Smith
Seung-Hyun Son, Postdoctoral Fellow
Charles Tang
George White
Yongsheng Wu

Ocean Circulation:
John Loder, Head

Term and casual employees, interns, students, and contractors are listed if they worked at BIO for at least four months in the year 2008.
* Retired in 2008 ** Deceased in 2008

Kumiko Azetsu-Scott
Frederic Dupont, Research Associate
Yuri Geshelin
Blair Greenan
Lanli Guo, Visiting Scientist
Helen Hayden
Ross Hendry
Zhenxia Long
Youyu Lu, Visiting Scientist
Ryan Mulligan, Visiting Scientist
William Perrie
Tara Rumley
David Slauenwhite
Xie Tao, Visiting Fellow
Brenda Topliss
Bash Toulany
Zeliang Wang
Dan Wright
Zhigang Xu, Visiting Scientist
Igor Yashayaev
Biao Zhang, Visiting Fellow
Lujun Zhang, Visiting Scientist

Ocean Physics:
Tim Milligan, Head
Jay Barthelotte
Brian Beanlands
Don Belliveau
Kelly Bentham
Rick Boyce
Derek Brittain
Zachariah Chiasson
Norman Cochrane
John Conrod
Mylene DiPenta
Helen Dussault
Richard Eisner*
Bob Ellis
Jim Hamilton
Adam Hartling
Bethany Johnson
Bruce Julien
Randy King
Daniel Moffatt
Glen Morton
Neil MacKinnon
Val Pattenden
Todd Peters
Merle Pittman
Nelson Rice
Bob Ryan
Murray Scotney
Greg Siddall
George States
Leo Sutherby

Ocean Data and Information Services:
John O'Neill, Section Head
Karen Atkinson
Lenore Bajona
Flo Hum
Jeffrey Jackson
Anthony Joyce
Marion Smith*
Tobias Spears
Kohila Thana
Patrick Upson

Population Ecology Division
Ross Claytor, Manager
Margrit Acker
Peter Amiro
Shelley Armsworthy
Julio Araujo, Postdoctoral fellow
Jerry Black
Shelley Bond
Don Bowen
Heather Bowlby
Rod Bradford
Josh Brading
Bob Branton*
Jason Bryan
Alida Bundy
Steve Campana
Dollie Campbell
Henry Caracristi
Lori Carrigan
Manon Cassista-DaRos
Jae Choi
Peter Comeau
Adam Cook
Michele Covey
Tania Davignon-Burton
Louise de Mestral Bezanson
Cornelia den Heyer
Wanda Farrell
Mark Fowler
Cheryl Frail
Jamie Gibson
Amy Glass
Sara Graham
Carolyn Harvie
Brad Hubley
Peter Hurley
Eric Jefferson
Ian Jonsen
Warren Joyce
Raouf Kilada
Peter Koeller
Mark Lundy
Bill MacEachern
Linda Marks
Danielle Matthews
Chad McEwen
Tara McIntyre
Jim McMillan
Marta Mihoff
Bob Miller*
Bob Mohn
Denise Muise
Rachelle Noel-Carter
Steve Nolan
Shane O'Neil
Patrick O'Reilly
Doug Pezzack
Alan Reeves
Dale Roddick
Sherrylynn Rowe
Karen Rutherford*
Jessica Sameoto
Bob Semple
Glyn Sharp
Mark Showell
Angelica Silva
Jim Simon
Stephen Smith
Debbie Stewart*
John Tremblay
Kurtis Trzcinski
Herb Vandermeulen
Megan Wilson
Sophie Whoriskey
Daisy Williams
Scott Wilson
Linda Worth-Bezanson
Gerry Young
Ben Zisserson

Population Ecology Division Offsite Employees:
Mary Allen
Judy Anderson
Leroy Anderson
Krissy Atwin
Denzil Bernard
Christopher Carr
Corey Clarke
Bev Davison
Sean Dolan
Gilbert Donaldson
Jim Fennell
Claude Fitzherbert

Term and casual employees, interns, students, and contractors are listed if they worked at BIO for at least four months in the year 2008.
* Retired in 2008 ** Deceased in 2008

Jason Flanagan
David Francis
Darrell Frotten
Trevor Goff
Michael Goguen
Randy Guitar
Ross Jones
Craig Keddy
Beth Lenentine
Philip Longue
Bill MacDonald*
Danielle MacDonald
John Mallery
Andrew Paul
Greg Perley
Rod Price*
Francis Solomon
Louise Solomon
Michael Thorburne
Malcolm Webb
John Whitelaw
Ricky Whynot
William Whynot

Gulf Fisheries Centre – Diadromous Fish Section
Paul LeBlanc

Strategic Planning, Advisory Activities and Outreach Division
Tom Sephton, manager
Kathryn Cook, Student
Joni Henderson
Valerie Myra
Lisa Savoie
Sarah Shiels, Student
Tana Worcester

Oceans, Habitat and Species at Risk Branch

Regional Director's Office
Michael Murphy, Regional Director
Trudy Wilson
Paul Boudreau

Environmental Assessment and Major Projects Division
Ted Potter, Regional Manager
Ted Currie
Denise McCullough
Mark McLean
Leslie Ouellette

Habitat Protection and Sustainable Development Division
Mike Cherry, Regional Manager
Joe Crocker
Rick Devine
Anna Dorey
Joy Dubé
Beverley Grant
Anita Hamilton
Janet Hartling
Tony Henderson
Darren Hiltz
Carol Jacobi
Rugi Jalloh
Brian Jollymore
Jim Leadbetter*
David Longard
Melanie MacLean (Habitat)
Kurt McAllister
Shayne McQuaid
Stacey Nurse
Greig Oldford
Ed Parker
Marci Penney-Ferguson
Peter Rodger
Colleen Smith
Reginald Sweeney**
Bruce Walker

Oceans and Coastal Management Division
Tim Hall, Regional Manager
Betty Beazley
Heather Breeze
Scott Coffen-Smout
Kristian Curran
Penny Doherty
Dave Duggan
Derek Fenton
Jennifer Ford
Aimee Gromack
Jennifer Hackett
Glen Herbert
Tracy Horsman
Marty King
Melanie MacLean (Oceans)
Stanley Johnston
Paul Macnab
Jason Naug
Nancy Shackell
Heidi Schaefer
Anna Serdynska
Maxine Westhead

Program Planning and Coordination
Odette Murphy, Branch Assistant Regional Director
Janet Gilbey
Carol Simmons
Jane Avery
Debi Campbell
Nancy Fisher
Joanne Perry

Species at Risk Coordination Office
David Millar, Regional Manager
Diane Beanlands
Lynn Cullen
Friederike Kirstein
Melissa McDonald
Kimberly Robichaud-LeBlanc
Dawn Sephton
Koren Spence

Fisheries and Aquaculture Management

Aquaculture Management Office
Cindy Webster, A/Director
Lorne Penny
Tammy Rose-Quinn
Sharon Young

Finance and Administration Branch

Material Services (Stores)
Larry MacDonald, Disposal, Warehousing Supervisor
Sean Byrne
Bob Page

Real Property Safety and Security Branch
Brian Thompson, Senior Site Leader*

Communications Branch

Luke Gaulton
Francis Kelly
Carl Myers

Information Management and Technology Services

Scott Graham, Regional Director, Informatics
Doug Earle, Chief, Planning and Information Management Services
Gary Somerton, Manager, Infrasturcture and Operation (Data Centre)
Paulette Bertrand
Elizabeth Hand
Andre J.A. Tremblay

Term and casual employees, interns, students, and contractors are listed if they worked at BIO for at least four months in the year 2008.
* Retired in 2008 ** Deceased in 2008

Data Centre:
Todd Beal
Patrice J. Boivin
Philip Comeau
Bruce F. Fillmore
Judy Fredericks
Sandra Gallagher
Pamela Gardner
Ron Girard
Marc Hemphill
Nathan T. Lavictoire
Carol Levac
Charles Mason
Juanita Pooley
Andrea Segovia
Mike Van Wageningen

Networks:
Mike Clarke
Susan Paterson
Paul E. Thom
Paddy Wong

Service Desk:
Francis MacLellan
Jim Middleton
Roeland Migchelsen

Telephony:
Terry Lynn Connolly

Library
Anna Fiander, Chief
Rebecca Arsenault
Rhonda Coll
Lori Collins
Lois Loewen
Maureen Martin
Marilynn Rudi

Records
Jim Martell*, Supervisor
Tara Rioux, Supervisor
Myrtle Barkhouse
Carla Sears

NATURAL RESOURCES CANADA

Geological Survey Of Canada (Atlantic)

Director's Office
Stephen Locke, Director GSC Atlantic
Pat Dennis
Judith Ryan

Marine Resources Geoscience
Mike Avery
Jennifer Bates
Ross Boutilier
Bob Courtney
Bernie Crilley*
Maureen Cursley
Claudia Currie
Sonya Dehler
Kevin DesRoches
Rob Fensome
Carmelita Fisher
Peter Giles
Gary Grant
Evelyn Inglis
Ruth Jackson
Chris Jauer
Nelly Koziel
Paul Lake
Bill MacMillan
Anne Mazerall
Patsy Melbourne
Phil Moir
Gordon Oakey
Phil O'Regan
Russell Parrott
Stephen Perry
Patrick Potter
Matt Salisbury
John Shimeld
Phil Spencer
Barbara Szlavko
Frank Thomas*
Hans Wielens
Graham Williams
Marie-Claude Williamson

Marine Environmental Geoscience
Ken Asprey
Anthony Atkinson
Darrell Beaver
Robbie Bennett
Steve Blasco
Owen Brown
Gordon Cameron
Calvin Campbell
Borden Chapman
Robert Fitzgerald
Donald Forbes
Paul Fraser
David Frobel
Robert Harmes
Scott Hayward
Azharul Hoque
Sheila Hynes
Kate Jarrett
Kimberley Jenner
Edward King
Vladimir Kostylev
Bill LeBlanc
Michael Li
Maureen MacDonald
Kevin MacKillop
Bill MacKinnon
Desmond Manning
Gavin Manson
Susan Merchant
Patrick Meslin
Bob Miller*
David Mosher
Bob Murphy
Michael Parsons
Eric Patton
Dick Pickrill
David Piper
Peter Pledge
Walta Rainey
Angus Robertson
John Shaw
Steve Solomon
Gary Sonnichsen
Bob Taylor
Brian Todd
Dustin Whalen
Bruce Wile

UNCLOS Program Office

Jacob Verhoef, Director

Shared Services Office

George McCormack, Manager
Cheryl Boyd
Terry Hayes
Cecilia Middleton
Julie Mills
Christine Myatt
Wayne Prime
Barb Vetese

ESS Office

Andy Sherin

Term and casual employees, interns, students, and contractors are listed if they worked at BIO for at least four months in the year 2008.
* Retired in 2008 ** Deceased in 2008

PUBLIC WORKS AND GOVERNMENT SERVICES

Leo Lohnes, Property Manager
Tony Barkhouse
Tim Buckler
Bob Cameron
Paul Fraser
Jim Frost
Garry MacNeill
John Miles
Craig Sanford
Arthurina Smardon
Phil Williams
Bill Wood

COMMISSIONAIRES

William Bewsher
Paul Bergeron
Dave Cyr
Marilyn Devost
Monique Doiron
Roger Doucet
John Dunlop
Donnie Hotte
Francis Noonan
Dave Smith
Don Smith
Daniel Wynn

CAFETERIA STAFF

Kelly Bezanson
Lynn Doubleday
Mark Vickers

OTHERS ON THE BIO CAMPUS

International Ocean-Colour Coordinating Group (IOCCG)
Venetia Stuart, Executive Scientist

Fishermen and Scientists Research Society (FSRS)
Jeff Graves
Carl MacDonald
Tricia Pearo
Shannon Scott-Tibbetts

Geoforce Consultants Ltd.
Ryan Pike
Dwight Reimer
Graham Standen
Martin Uyesugi

Contractors
Derek Broughton, Population Ecology
Darlene Brownell, Ocean Circulation
Jason Burtch, Coastal Ocean Science
Kate Collins, Coastal Ocean Science
Barbara Corbin, Records
Ewa Dunlap, Coastal Ocean Science
Maud Guarracino, Coastal Ocean Science
Susan Hannan, Ocean Circulation
Yongcun Hu, Ocean Data and Information Services
Jennifer Lavallee, COOGER
Chris L'Esperence, Ocean Circulation
Xiacwei Ma, COOGER
Alan McLean, CHS
Jeff Potvin, Informatics
Nicole Prinsenburg, COOGER
Daniel Ricard, Population Ecology
Ron Selinger, Records
Gerald Siebert, Ocean Circulation
Victor Soukhovtsev, Coastal Ocean Science
Jacquelyn Spry, Ocean Research and Monitoring
Jenny Take, CHS
Tineke van der Baaren, Coastal Ocean Science
Rob Walters, CHS
Alicia Williams, Population Ecology
Kari Workman, COOGER
Inna Yashayaeva, Ocean Data and Information Services

Scientist Emeritus/Science Alumnus
Piero Ascoli
Allyn Clarke
Ray Cranston
Subba Rao Durvasula
Jim Elliott
George Fowler
Donald Gordon
Alan Grant
Doug Gregory
Ralph Halliday
Gareth Harding
Iris Hardy
Bert Hartling
Alex Herman
Lubomir Jansa
Brian Jessop
Peter Jones
Charlotte Keen
Paul Keizer
Tim Lambert
René Lavoie
Mike Lewis
David McKeown
Brian MacLean
Ken Mann
Clive Mason
Peta Mudie
Neil Oakey
Doug Sameoto
Hal Sandstrom
Charles Schafer
Shiri Srivastava
James Stewart
John Wade

Recognition

BIO staff wish to recognize the contribution and support provided by the Captains and crews of Canadian Coast Guard vessels tasked to assist scientific research at BIO.

Term and casual employees, interns, students, and contractors are listed if they worked at BIO for at least four months in the year 2008.
* Retired in 2008 ** Deceased in 2008

Retirements 2008

Retirement notices are prepared usually by colleagues in the organizations where the retirees were employed.

Cynthia Bourbonnais-Boyce retired in October after 30 years with DFO. Cynthia joined the Marine Ecology Laboratory in the summer of 1978 and provided technical support to the St. Georges Bay program based at the field station in Crystal Cliffs, Antigonish County. The following year, she assumed the duties of a technician in the newly established Marine Fish Division. For many years, she worked on the observer program, studied silver hake, and participated in annual trawl surveys, including those for juvenile silver hake on Russian vessels. Seeking a change, in 1996 she transferred to the Habitat Ecology Division and began working with benthic invertebrates in the taxonomy laboratory. Cynthia played a leading role in the processing of videograb samples that were collected as part of major experiments investigating the impacts of mobile fishing gear on benthic habitat and biological communities. She also made important contributions to the development and operation of the deep-water coral program. Her last major project was working with the large team of scientists and engineers studying the spatial distribution of preferred seabed habitat for demersal fish on the Scotian Shelf. Throughout her career, Cynthia loved to go to sea no matter what the weather or ship. She was an excellent field technician who always got the job done, even under unpleasant conditions. Over the years, she made many important contributions to the fisheries, habitat, and biodiversity science programs in DFO and her expertise and enthusiasm will be missed.

Robert M. Branton retired from DFO in March after almost 34 years of public service with the Marine Fish Division and then Population Ecology Division at BIO. Bob served as a lead in data management, as a Redfish species biologist, and as a head of the data management section. He actively supported the Ocean Biogeographic Information System, known as OBIS, and was a champion of improving the metadata information describing survey data. In retirement, Bob became Director, Data Management for the newly formed Dalhousie University, Faculty of Science Ocean Tracking Network (OTN). In addition to his work with OTN, Bob is a Science Alumnus at BIO and continues to be involved in various science informatics initiatives including: the Centre for Marine Biodiversity Technical Committee, the Coastal and Ocean Information Network for the Atlantic, and the Gulf of Maine Ocean Data Partnership.

Bernie Crilley retired in January after more than 30 years as a Palynology Laboratory technician with Geological Survey of Canada (Atlantic), Natural Resources Canada. Bernie joined the organization, then the Atlantic Geoscience Centre, in January 1975 after graduating as a chemical technologist from the New Brunswick Community College. During his tenure, Bernie refined many palynology processing techniques and was renowned for managing the laboratory economically. He was a member of the BIO Lab Occupational Health and Safety Committee for about 15 years and co-chaired the committee for most of that time.

Elizabeth Crux retired in January after 30 years with the Canadian Hydrographic Service (CHS). Elizabeth started her career in Ottawa in 1977 as a nautical chart compiler, which utilized her training in cartography from the Geography Department of the London School of Economics. When the CHS decentralized in 1978 she moved to BIO. As well as compiling numerous nautical charts, Elizabeth occasionally went into the field to conduct hydrographic surveys. While on a survey in Bonavista Harbour, she found it satisfying to observe the replica of John Cabot's *Matthew* arriving, using a chart that she had compiled, making the approach far safer than it had been for the original vessel in 1497. Elizabeth compiled the original from which the Lakes and Rivers sheets of *The Revised Atlas of Canada* was made. This was the source of the illuminated map now in the BIO auditorium. She spent her last years in the CHS compiling written and graphic "patches" for Notices to Mariners, to advertise critical chart information. Elizabeth's creativity was showcased at BIO, e.g., her musical talents and choreography at variety shows and intricate gowns and other handwork at employee arts-and-crafts exhibits. She contributed her time to the BIO Canadian Cancer Society daffodil campaign and the annual CHS Christmas party. In retirement, Elizabeth will pursue her music and many interests of a historical nature including the Medieval Society, period re-enactments, and costumes.

Richard A. Eisner worked for DFO Science for 37 years, after completing his Bachelor of Science, then a year of graduate studies in Biochemistry at Dalhousie University. He joined DFO in the Salmon Hatchery Manager training program and worked at the Antigonish and Mactaquac fish culture facilities before managing the Kejimkujik Fish Culture Station. Shortly after that he assumed the position in Halifax of District Supervisor for Northern Culture Stations. The creation of the Gulf Region was the opportunity for Richard to move to Moncton as Section Head for Fish Culture Stations for the Gulf Region. He soon became the Assistant Regional Director of Science for the Gulf Region. The DFO Program Review in 1993-94 resulted in the amalgamation of the Scotia-Fundy and Gulf regions into the Maritimes Region and the relocation of Richard to BIO, to become the Manager for Program Planning and Coordination for Science, Maritimes Region. During his 37 years he was involved in a variety of activities such as helping develop a new feed for Atlantic salmon, renovating salmon hatcheries, overseeing the Year 2000 efforts in Science, and being the Canadian lead for the Global Ocean Biogeographic Information System. He was a master at finding financial

support for a wide range of critical infrastructure for BIO, SABS, and the biodiversity facilities. Richard will retain his activities as Treasurer for the A.G. Huntsman Foundation while he enjoys his Scientist Emeritus work at BIO.

Jim Leadbetter retired in April from the Oceans, Habitat and Species at Risk Branch, after 35 years with DFO. Jim began his career in 1973 with Science Branch; in 1986, he joined the Habitat Management Program. A personable and professional colleague, he had an impressive knowledge about habitat and a passion for protection of fish habitat. Among his numerous career accomplishments was his visionary contribution to the foundation of the Habitat Management Program and its many successes. Jim never lost sight of his goals, and his achievements, along with his outstanding commitment to fish habitat protection, earned him the trust and respect of departmental staff and industry representatives. He was also a natural mentor and teacher, appreciated across the country for sharing his library and as a fish habitat protection guru. Jim's dedication, skills, knowledge, and efforts made a difference to the success of many DFO initiatives. It became apparent that he will be greatly missed when so many colleagues, industry representatives, and friends from across the country travelled to attend his retirement celebration. Jim is looking forward to spending time with his family and pursing his many hobbies, which include home renovations, snowboarding, and surfing.

William MacDonald retired from DFO in September after 27 years of service. Bill started work at the Mactaquac Fish Culture Station (now Biodiversity Facility) as a truck driver in June 1980. He became a Hatchery Assistant/Fish Transporter in 1999, the position he held until his retirement. Bill's skills as a "fish transporter" will be greatly missed, as well as his reliability and cheerful manner. He received a Group (Team) Merit Award in 2001 as a member of the Mactaquac staff and Engineering Division team that was nominated in four national criteria, including high level of performance over an extended time. Upon his retirement, Bill was the recipient of a DFO Immediate Award in recognition of his 27 years of accident-free driving. DFO appreciated the commitment he demonstrated over his career, safely transporting millions of fish in excess of a million kilometres, often over rough terrain and to very remote areas using various types of vehicles. Bill graciously returned to Mactaquac to help complete the fall distributions and train new drivers. His colleagues will miss his interesting and colourful trip debriefings and stories.

Jim Martell retired in June from the DFO Records Office after more than 40 years with the Public Service of Canada. Jim started his career in 1966, with the Department of National Defence at Canadian Forces Base Halifax Stadacona. He joined DFO at BIO in 1975, as the Supervisor of Mail Operations, Photocopying Services and Communications. After years of reading the scientific material arriving through the mail and conversing with staff, Jim entered the field of classifying the subject matter in the Records Office. Classification of the incoming correspondence gave him the insight into what is being accomplished at the Institute, at the same time it allowed him to expand his knowledge of records management. Upon retirement, he was Site Supervisor for the Records Office at the BIO complex. At BIO, Jim was actively involved in his union local where he volunteered his service to financial affairs. He was one of the original volunteer committee members of the BIO United Way Golf Tournament and particularly enjoyed participating in several BIO Open House celebrations. He claims that showing and informing the public of what took place at the Institute was very fulfilling and he was proud to be employed at BIO. In his retirement, Jim is enjoying spending time with his family and on the golf course.

Robert J. Miller retired from BIO in January 2007. Bob began his DFO career in 1969 as a Postdoctoral Fellow at the Marine Ecology Lab. At the Newfoundland Biological Station from 1971-79, he wrote the first fishery management plan for the Atlantic snow crab fishery and began a long-term research interest on the functioning of baited traps. After moving to the Halifax Lab in 1979 he investigated energy flow through shallow-water benthic communities. There, and subsequently at BIO, Bob participated in the development of new fishery management plans for sea urchins, rock crabs, Jonah crabs, and blood worms and advised on management of lobster fisheries. With several co-workers he studied lobster larval dynamics as bottlenecks to population production. He was a manager for several years in Newfoundland and Nova Scotia. Career highlights included insights into how nature works, improvements to resource sustainability and fishers' incomes for a few fisheries, sabbaticals in Nanaimo, Barbados, and The Netherlands, and, with Fred Rahey and Ron Duggan, the operation of a small public aquarium on the Halifax waterfront. Bob continues at BIO as a Scientist Emeritus, writing papers he says he should have written years ago.

Robert O. Miller retired from Natural Resources Canada in July after 34 years at BIO. After graduating from the Cambrian College of Applied Arts and Technology in Sudbury as a geological technician in 1972, Bob joined NRCan (formerly Energy, Mines, and Resources) at BIO, assisting Dr. Lew King as he established the early methods of marine geological mapping. His career spanned Baffin Island, Labrador Shelf, the Grand Banks, Cabot Strait, Scotian Shelf, and the Bay of Fundy. A highlight for Bob was his role as Senior Scientist for several focused seabed mapping expeditions in Nova Scotia and New Brunswick inlets – Halifax Harbour being the most prominent. This research culminated in the GSC Bulletin, *The Surficial Geology of Halifax Harbour*, which he co-authored with Gordon Fader. Known by many as "Radar", Bob was an organizer of many of the BIO dances as well as a participant in other BIO social events and staff functions. His extracurricular activities include baseball, hockey, golf, cross-country skiing, and especially playing the harmonica with local bands. Many of these musician friends entertained as they, along with his sports' and BIO families, celebrated at his retirement party.

Richard Palmer retired in April after 35 years with the CHS. Richard graduated from Dalhousie University with a Bachelor of Science in Mathematics and Physics. He joined the CHS at BIO in 1973 as a field hydrographer. Over the years, he has sailed on the CSS *Maxwell*, CSS *Baffin*, and CCGS *Matthew* carrying out bathymetric and tidal surveys throughout most of Eastern Canada, including the Arctic. In 1987 Richard joined the newly formed district

office in St. John's, Newfoundland; during his last two years there he was Hydrographer-in-Charge. He returned to BIO in 1997, to supervise Data Transformation, specializing in Notices to Mariners. Richard's ethics and generosity in sharing his expertise (and chocolate) were well known and appreciated. He was always proud to wear the CHS crest and considered his career to be the best he could have. In retirement, Richard is continuing his studies at Dalhousie University and is taking drawing courses at the Nova Scotia College of Art and Design.

Rod Price first worked for DFO in the summers of 1965 and 1966, electrofishing (live sampling for assessment) juvenile Atlantic salmon on the Miramichi River and later, assisting in operating the Mactaquac Dam Fishway. In 1967, he started working at the Mactaquac Fish Culture Station (now, Biodiversity Facility) in Mactaquac, New Brunswick, before its completion and official opening in October 1968. In 1972, he became Fishway Operator Supervisor and the following year, Manager. As Fishway Manager, Rod's keen eye, understanding of fish behavior, and excellent communication and negotiation skills led to the existing operational protocols DFO has with NB Power for both upstream and downstream fish passage at the three dams on the Saint John River. After 30 years as Fishway Manager, in 2005 he became one of Mactaquac's three Technical Supervisors. He excelled in this position that involved supervising all aspects of the Fish Culture program and the sorting and transport of adult salmon upriver past the Saint John Mactaquac hydroelectric dam. Rod received a DFO Merit award in 2001 as a member of the Mactaquac team. For his exceptional performance mentoring a YMCA youth intern in 2007, DFO's Regional Director of Science presented him with a special award. He retired in March after 41 years of dedicated service to DFO. Rod's professional skills, commitment, and engaging personality will be greatly missed, as will his generous lunchroom cooking.

Karen Rutherford retired from DFO's Population Ecology Division in June after 35 years of service as a biological technician. Karen began as a biological technician in the former Freshwater and Anadromous Division of the Resource Development Branch, working several summers while completing her degree at Acadia University. Her early career saw her balancing her busy family life and the challenges of field work, much of it devoted to research projects on fish physiology and salmon enhancement programs. Karen's work took her to the salmon traps and fences on the Margaree, Sackville, St. Mary's and Northumberland shore rivers. In October, she could often be found snorkeling in a river, counting sea-run salmon for stock assessments. Her career highlights also included conducting creel surveys of salmon anglers on several Nova Scotia rivers in the 1980s and tracking fish in the Salmon River (among others) to monitor their movements in support of a population recovery project. While on field trips, Karen always enjoyed visiting restaurants around Nova Scotia and comparing experiences on the local delicacies with colleagues and friends. She is a great cook and generously treated her co-workers with baked treats from her kitchen every Monday for years. Although Karen has retired, she remains active helping with inner Bay of Fundy salmon recovery at the Coldbrook Biodiversity Facility and assisting the Population Ecology Division archive information and files.

Alan Smith retired from the CHS in January after 30 years at BIO. Alan began his career in 1972 as a cartographer with Maritime Resource Management Service creating thematic maps. He joined the CHS in 1978 as a cartographer and in the early 1980s took part in hydrographic field surveys on the CSS *Baffin* in Fortune Bay and the MV *Polar Circle* in Ungava Bay and Fox Basin. In 1982-83, he assisted the Tidal Unit with his scuba diving skills by replacing submersible tide gauges in Alert, Frobisher Bay/Iqaluit, Resolute, Hall Beach, and Fort Chimo/Kuujjuaq. Alan was a forefather in computer-assisted cartography within the CHS. He was a programmer and created scripts and documentation for interactive compilation that are still used for chart production. After completing Hydrographic Survey training in 1986, Alan became a multidisciplinary hydrodrographer and participated in revisory surveys in Guysborough County. Due to his extensive knowledge of chart production, he became a leader in the transition to electronic navigational chart production and the Hydrographic Production Database. Alan was heavily involved in his community, as a scout leader, soccer and softball coach, and curling instructor. His colleagues wish him all the best in his retirement. Alan will be greatly missed, as he now takes the time to enjoy his lifetime hobbies of fishing, curling, and gaming.

Marion Smith retired from DFO in September, after 32 years of service with the Ocean Sciences Division. Marion worked as a summer student in 1975 in Coastal Oceanography, before joining DFO as a permanent employee. Her entire career was with the data analysis group, providing technical support to research scientists in processing and analyzing physical oceanographic data. During her time at BIO Marion saw and participated in huge technological changes in computers, oceanographic instrumentation, and automated processing.

Deborah Stewart retired from her position as Assessment and Analysis support technician in the Population Ecology Division in July, after 28 years with DFO. Debbie began at DFO in 1980 as a statistical clerk in the Quota Monitoring Unit where she showed her proficiency with data: collecting, collating, summarizing, and reporting on fisheries catches. She joined the former Freshwater and Anadromous Division in 1989 and quickly established communication links with fishermen of diadromous species and their fisheries statistics, including the Atlantic salmon recreational fishing catch-and-effort reporting system for Nova Scotia. As changes occurred to the staff complement and duties, Debbie assumed a greater role in coordinating the information systems for the division. Before long she was managing several databases and developed a prowess at displaying data through Geographic Information Systems. She was a strong contributor to group activities with her unit and was quick to volunteer for such events as the BIO Open House. Debbie pursued a life-long interest in learning and maintaining a proficiency in French. She decided to retire because, in her words, "It's time to try something else". Debbie and her husband, Jerry, have taken on a new challenge with a new home on a "back 40" near Sackville, New Brunswick.

Brian Thompson retired in December after a long career with DFO. He is a graduate of Saint Mary's University, the Nova Scotia

Technical College, and Dalhousie University. In 1978, Brian joined DFO's Small Craft Harbours Branch where he held a number of progressively senior engineering and program management positions associated with harbour planning, maintenance, and development. Brian was seconded to the Habitat Management group in 1988, where, in 1995, he became Division Manager. During that time, the division was extensively involved with the environmental review of a number of major high-profile projects including offshore oil-and-gas exploration and development, natural gas pipeline construction, and major highway work. In 2001, Brian joined the Real Property Safety and Security Branch (RPSS) as a Senior Site Leader; in this position he later assumed responsibilities for BIO's redevelopment program. Redevelopment included projects such as the completion of the Vulcan Building and workshops, development and construction of the new Katherine Ellis Laboratory, reconstruction of the VanSteenburgh building, and approval for new jetty extension. Prior to his retirement, Brian served as Acting Regional Director of RPSS. Brian is looking forward to renewing and becoming more actively involved with a number of his personal passions such as photography, painting, gourmet cooking, camping, fly tying, and motorcycling.

Norwood Whynot retired in December 2007 after 35 years of service with DFO. Norwood joined the department in 1972 as a graphic illustrator with the Science Branch. His work included publication, design and production, technical illustrations, aerial and field photography, and rendering for reports, posters, and brochures. In 1982, he became the Regional Graphics Producer for the Communications Branch. His new responsibilities included co-ordinating the region's participation in trade shows and exhibitions. Norwood remained with the Communications Branch in positions that included Manager of Creative Services and Manager of Publishing and Imagery. He always enjoyed the creative aspect of his job and took pleasure in his involvement with trade shows, which allowed him to interact with employees and the public. His helpful nature combined with his years of expertise in graphics, advertising, and publishing led him to become a sought-after resource by all DFO branches and sectors in the Maritimes Region. In his retirement, Norwood plans to relax, travel, and do freelance design, fine art, and illustration.

Phil Yeats retired in December after a 35-year career. Phil arrived at BIO in 1973 as a National Research Council postdoctoral fellow in the Chemical Oceanography Division of the Atlantic Oceanographic Laboratory. During his postdoctoral period he addressed research issues associated with the geochemistry of nutrients in the Gulf of St. Lawrence. In 1974, Phil joined the permanent staff of DFO's Chemical Oceanography (subsequently Marine Chemistry) group and shifted his focus to the distribution, transport, and fate of heavy metals in sea water. During the following two decades, he became one of the leading investigators in a large international effort to establish robust techniques for the collection and analysis of trace metals in ocean waters, to certify the validity of these techniques and develop an understanding of the mechanisms governing their distributions. With the advent of the Green Plan for toxic metals, in the 1990s he shifted his focus to inshore problems related to coastal pollution and biological effects. Recently, Phil has rekindled his interest in offshore problems using chemical oceanographic data archived by researchers at BIO and elsewhere to investigate decadal scale trends in chemical parameters that are important to our understanding of the effects of climate change. He plans to continue this work as an emeritus scientist.

In Memoriam

Reginald Sweeney, an employee with the Habitat and Sustainable Development Division of the Oceans, Habitat and Species at Risk Branch, passed away on December 1, 2007.

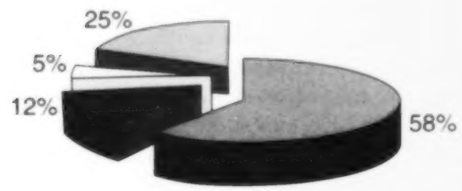
Reg was born in Pleasant Lake, Yarmouth County, Nova Scotia. His education began in a one-room schoolhouse and continued on to Acadia University, from where he graduated in 1971 with a Bachelor of Science degree. Reg began his career in DFO's Freshwater and Anadromous Fish Division in 1971. Dedicated to fish habitat research and management issues, in 1986 he was one of ten employees from the division to form the regional core of the new Habitat Management Division. Through his dedication, vast knowledge of the fish habitat realm, and keen grasp of Canadian environmental laws he became a pillar of the Habitat Management Program.

Reg excelled at and became intricately involved in regulatory reviews and environmental assessments of major industrial projects. He represented DFO on large-scale projects including the offshore oil and gas developments and associated pipeline construction. He was at the leading edge of fish habitat protection when habitat impact avoidance or mitigation was needed. Reg mentored many staff throughout his career, sharing his detailed knowledge of fish habitat, environmental management, and regulatory processes. His calm and insightful manner, together with his wealth of knowledge, gained him the highest respect among all who worked with him. To commemorate Reg's contribution to Canadians, the 5th floor boardroom in the Polaris Building at BIO has been named the Reg Sweeney Boardroom.

FINANCIAL AND HUMAN RESOURCES

Where BIO obtains funding and how it is spent

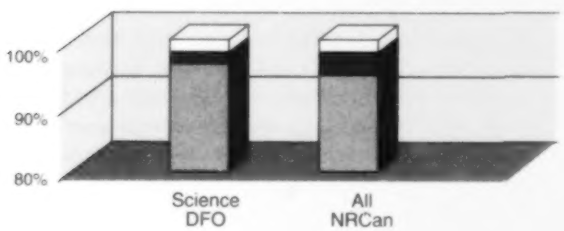
Annual appropriation from government



DEPARTMENT	SECTOR	AMOUNT ($000)
DFO	Science	29,354
DFO	OHSAR	5,920
NRCan	GSC	2,550
NRCan	UNCLOS	12,500

DFO Informatics, Environment Canada, and DND have staff working at BIO. The resources used by those staff members are not captured in this report.

Other sources of funding

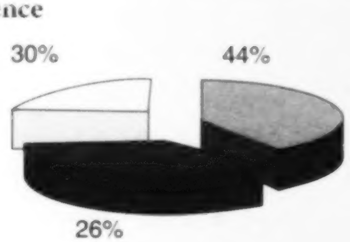


DEPARTMENT	SECTOR	GOVERNMENT ($000)	INSTITUTIONS ($000)	INDUSTRY ($000)
DFO	Science	11,244	1,002	1,281
NRCan	GSC & UNCLOS	3,800	600	300

Industry Institutions Government

DFO Science spending

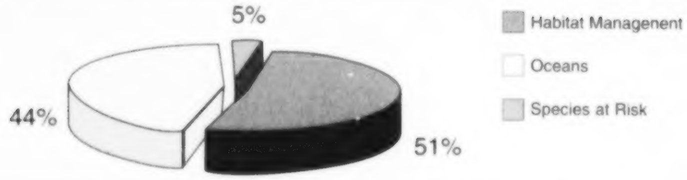
DFO Science



STRATEGIC OBJECTIVE	AMOUNT ($000)
Healthy and Productive Aquatic Ecosytems	14,352
Sustainable Fisheries and Aquaculture	8,696
Safe and Accessible Waterways	10,028

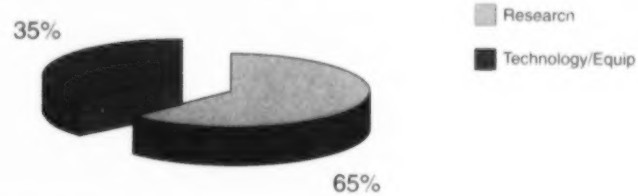
Program spending cont.

DFO Oceans, Habitat and Species at Risk



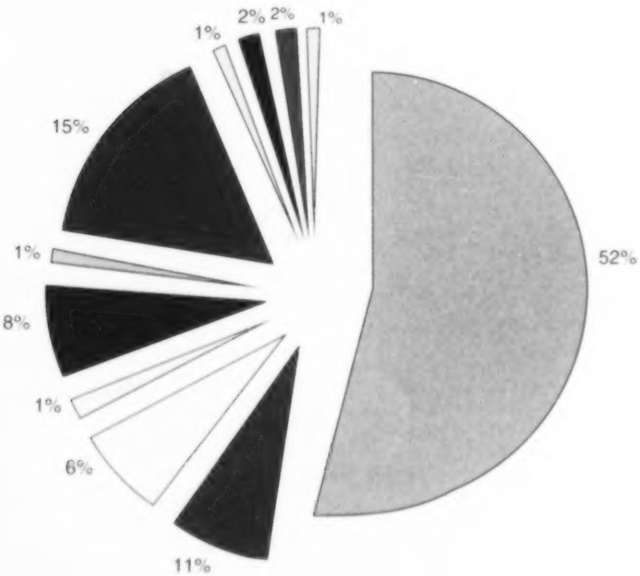
PROGRAMS	AMOUNT ($000)
Habitat Management	3,032
Oceans	2,598
Species at Risk	290

NRCan



	AMOUNT ($000)
Research	12,850
Technology/Equipment	6,900

BIO staff by Division/Department



DFO - Science	344
DFO - Oceans, Habitat & Species at Risk	60
DFO - Informatics	41
DFO - Other	15
DFO - Coast Guard Tech Services	40
DFO - Aquaculture Coordination	4
NRCan - GSC Atlantic	96
EC - Operational Laboratories	3
DND - Survey Office	15
PWGSC - Site Operations	13
Research Coordination Units	9
Total	640

Numbers are taken from the staff lists and do not include contractors, students, or emeritus scientists.

PUBLICATIONS AND PRODUCTS

Publications 2008

BEDFORD INSTITUTE OF OCEANOGRAPHY

SCIENTIFIC JOURNALS

DFO: Science Branch

Berreville, O.F., A.F. Vézina, K.R. Thompson, and B. Klein. 2008. Exploratory data analysis of the interactions among physics, food web structure, and function in two Arctic polynyas. Can. J. Fish. Aquat. Sci. 65: 1036-1046.

Bogden, P., J. Cannon, R.Y. Morse, I. Ogilvie, B. Blanton, and W. Perrie. 2008. Forecasting storm damage on the Maine coast. J. Ocean Technol. 3: 7-11.

Bradbury, I.R., B. Laurel, P.V.R. Snelgrove, P. Bentzen, and S.E. Campana. 2008. Global patterns in marine dispersal estimates: The influence of geography, taxonomic category and life history. Proc. R. Soc. Lond. B Biol. Sci. 275: 1803-1809.

Bradbury, I.R., S.E. Campana, and P. Bentzen. 2008. Otolith elemental composition and adult tagging reveal spawning site fidelity and estuarine dependency in rainbow smelt. Mar. Ecol. Prog. Ser. 368:255-268.

Bradbury, I.R., S.E. Campana, and P. Bentzen. 2008. Estimating contemporary early life-history in an estuarine fish: Integrating molecular and otolith elemental approaches. Mol. Ecol. 17: 1438-1450.

Bradbury, I.R., S.E. Campana, and P. Bentzen. 2008. Low genetic connectivity in an estuarine fish with pelagic larvae. Can. J. Fish. Aquat. Sci. 65: 147-158.

Bugden, J.B.C., C.W. Yeung, P.E. Kepkay, and K. Lee. 2008. Application of ultraviolet fluorometry and excitation-emission matrix spectroscopy (EEMS) to fingerprint oil and chemically dispersed oil in seawater. Mar. Pollut. Bull. 56: 677-685.

Bundy, A., R. Chuenpagdee, S. Jentoft, and R. Mahon. 2008. If science is not the answer, what is? An alternative governance model for the world's fisheries. Front. Ecol. Environ. 6(3): 152-155.

Campana, S.E., J.M. Casselman, and C.M. Jones. 2008. Bomb radiocarbon chronologies in the Arctic, with implications for the age validation of lake trout (*Salvelinus namaycush*) and other Arctic species. Can. J. Fish. Aquat. Sci. 65: 733-743.

Campana, S.E., W. Joyce, L. Marks, P. Hurley, L. Natanson, N.E. Kohler, C.F. Jensen, J.J. Mello, H.L. Pratt, Jr., S. Myklevoll, and S. Harley. 2008. The rise and fall (again) of the porbeagle shark population in the Northwest Atlantic, p. 445-461. *In* M.D. Camhi, E.K. Pikitch, and E.A. Babcock [ed.]. Sharks of the Open Ocean: Biology, Fisheries and Conservation. Blackwell Publishing, Oxford, U.K.

Chen Z., L. Zhao, K. Lee, and C. Hannah. 2007.* Modeling and assessment of the produced water discharges emitted from offshore petroleum platforms. Water Qual. Res. J. Can. 42(4): 303-310.

Chen, C., A. Amirbahman, N. Fisher, G. Harding, C. Lamborg, D. Nacci, and D. Taylor. 2008. Methylmercury in marine ecosystems: Spatial patterns and processes of production, bioaccumulation, and biomagnification. EcoHealth. (doi:10.1007/s10393-008-0201-1)

Croll, R.P., S. Currie, and J. Hellou. 2008. Back to basics in aquatic toxicology. Integr. Environ. Assess. Manag. 4: 520-521.

Dillane, E., P.G. McGinnity, J.P. Coughlan, M.C. Cross, E. Kenchington, and T.F. Cross. 2008. Landscape features influence intra-river population genetic structure in Atlantic salmon (*Salmo salar L.*). Mol. Ecol. 17: 4786-4800.

Elsdon, T.S., B.K. Wells, S.E. Campana, B.M. Gillanders, C.M. Jones, K.E. Limburg, D.H. Secor, S.R. Thorrold, and B.D. Walther. 2008. Otolith chemistry to describe movements and life-history parameters of fishes – hypotheses, assumptions, limitations and inferences. Oceanogr. Mar. Biol. Ann. Rev. 46: 297-330.

Feistel, R., D.G. Wright, K. Miyagawa, A.H. Harvey, J. Hruby, D.R. Jackett, T.J. McDougall, and W. Wagner. 2008. Mutually consistent thermodynamic potentials for fluid water, ice and seawater: A new standard for oceanography. Ocean Sci. 4: 275-291. (www.ocean-sci.net/4/275/2008)

* Citation year is 2007; however, publication occurred only after publication of "Bedford Institute of Oceanography 2007 in Review".

Fisher, J.A.D., K.T. Frank, B. Petrie, W.C. Leggett and N.L. Shackell. 2008. Temporal dynamics within a contemporary latitudinal diversity gradient. Ecol. Lett. 11: 883-897.

Francis, M.P., L.J. Natanson, and S.E. Campana. 2008. The biology and ecology of the porbeagle shark, *Lamna nasus*, p. 105-113. *In* M.D. Camhi, E.K. Pikitch, and E.A. Babcock [ed.]. Sharks of the Open Ocean: Biology, Fisheries and Conservation. Blackwell Publishing, Oxford, U.K.

Gagne, F., T. Burgeot, J. Hellou, S. St-Jean, E. Farcy, and C. Blaise. 2008. Spatial variations in biomarkers of *Mytilus edulis* mussels at four polluted regions spanning the Northern Hemisphere. Environ. Res. 107(2): 201-217.

Grant, J., C. Bacher, P.J. Cranford, T. Guyondet, and M. Carreau. 2008. A spatially explicit ecosystem model of seston depletion in dense mussel culture. J. Mar. Syst. 73: 155-168.

Greenan, B.J.W. 2008. Shear and Richardson number in a mode-water eddy. Deep-Sea Res. Pt. II. 55: 1161-1178.

Greenan, B.J.W., B.D. Petrie, W.G. Harrison, and P. M. Strain. 2008. The onset and evolution of a spring bloom on the Scotian Shelf. Limnol. Oceanogr. 53: 1759-1775.

Hannah, C.G. 2007.* Future directions in modelling physical-biological interactions. Mar. Ecol. Prog. Ser. 347: 301–306. (doi: 10.3354/meps06987)

Hargrave, B.T., L.I. Doucette, K. Haya, F.S. Friars, and S.M. Armstrong. 2008. A micro-dilution method for detecting oxytetracycline-resistant bacteria in marine sediments from salmon and mussel aquaculture sites and an urbanized harbour in Atlantic Canada. Mar. Pollut. Bull. 56: 1439-1445.

Hargrave, B.T., L.I. Doucette, P.J. Cranford, B.A. Law, and T.G. Milligan. 2008. Influence of mussel aquaculture on sediment organic enrichment in a nutrient-rich coastal embayment. Mar. Ecol. Prog. Ser. 365: 137-149.

Hargrave, B.T., M. Holmer, and C.P. Newcombe. 2008. Towards a classification of organic enrichment in marine sediments by the use of biogeochemical indicators. Mar. Pollut. Bull. 56: 810-824.

Hellou, J., K. Cheeseman, E. Desnoyers, D. Johnston, M.L. Jouvenelle, J. Leonard, S. Robertson, and P. Walker. 2008. A non-lethal chemically based approach to investigate the quality of harbour sediments. Sci. Tot. Environ. 389: 178-187.

Huang, Y., B. Yin, and W. Perrie. 2008. Responses of summertime extreme wave heights to local climate variations in the East China Sea. J. Geophys. Res. 113, C09031. 13 p. (doi:10.1029/2008JC004732)

Hubley, P.B., P.G. Amiro, A.J.F. Gibson, G.L. Lacroix, and A.M. Redden. 2008. Survival and behaviour of migrating Atlantic salmon (*Salmo salar L.*) kelts in river, estuarine, and coastal habitat. ICES J. Mar. Sci. 65: 1626–1634.

Hubley, P.B., P.G. Amiro, and A.J.F. Gibson. 2008. Changes in scale circulus spacings of an endangered Atlantic salmon *Salmo salar* population: Evidence of a shift in marine migration? J. Fish Biol. 73: 2321–2340.

Hutchings, J.A., and S. Rowe. 2008. Consequences of sexual selection for fisheries-induced evolution: An exploratory analysis. Evol. Appl. 1: 129-136.

Ibrahim, A.M., R.H. Aly, E. Kechington, and T.G. Ali. 2008. Genetic polymorphism among five populations of *Pinctada radiata* from the Mediterranan coast in Egypt indicated by RAPD-PCR technique. Eqypt. J. Zool. 50: 467-477.

Jeansson, E., S. Jutterström, B. Rudels, L.G. Anderson, K. Anders Olsson, E.P. Jones, W.M. Smethie, Jr., and J.H. Swift. 2008. Sources to the East Greenland Current and its contribution to the Denmark Strait overflow. Prog. Oceanogr. 78: 12-28.

Jessop, B.M., D.K. Cairns, I. Thibault, and W.N. Tzeng. 2008. Life history of American eel *Anguilla rostrata*: New insights from otolith microchemistry. Aquat. Biol. 1(3): 205-216.

Jessop, B.M., J.C. Shiao, Y. Iizuka, and W.N. Tzeng. 2008. Prevalence and intensity of occurrence of vaterite inclusions in aragonite otoliths of American eels Anguilla rostrata. Aquat. Biol. 2: 171-178.

Jiang, J., and W. Perrie. 2008. Climate change effects on North Atlantic cyclones. J. Geophys. Res. 113, D09102. 6 p. (doi:10.1029/2007JD008749)

Johnson, C.L., A.W. Leising, J.A. Runge, E.J.S. Head, P. Pepin, S. Plourde, and E.G. Durbin. 2008. Characteristics of *Calanus finmarchicus* dormancy patterns in the Northwest Atlantic. ICES J. Mar. Sci. 65: 339-350.

Jones, E.P., L.G. Anderson, J. Jutterstrom, and J.H. Swift. 2008. Sources and distribution of fresh water in the East Greenland Current. Prog. Oceanogr. 78: 37-44.

* Citation year is 2007; however, publication occurred only after publication of "Bedford Institute of Oceanography 2007 in Review".

Jones, E.P., L.G. Anderson, S. Jutterström, L. Mintrop, and J.H. Swift. 2008. Pacific freshwater, river water and sea ice meltwater across Arctic Ocean basins: Results from the 2005 Beringia Expedition. J. Geophys. Res. 113, C08012. (doi:10.1029/2007JC004124).

Jutterström, S., E. Jeansson, L.G. Anderson, R. Bellerby, E.P. Jones, W.M. Smethie, Jr., and J.H. Swift. 2008. Evaluation of anthropogenic carbon in the Nordic Seas using observed relationships of N, P and C versus CFCs. Prog. Oceanogr. 78. 78-86.

Kilada, R., and R. Riad. 2008. Seasonal variations in biochemical composition of *Loligo forbesi* (Cephalopoda: Loliginidae) in the Mediterranean and Gulf of Suez, Egypt. J. Shellfish Res. 27: 1-8.

King, T.L. 2008. Risk estimates: Polycyclic aromatic hydrocarbons in Sydney Harbour sediments and lobster. Proc. N.S. Inst. Sci. 44(2): 187-200.

Koeller, P. 2007.* Ecosystem-based psychology, or how I learned to stop worrying and love the data. Fish. Res. 90/1-3: 1-5.

Law, B.A., P.S. Hill, T.G. Milligan, K.J. Curran, P.L. Wiberg, and R.A. Wheatcroft. 2008. Size sorting of fine-grained sediments during erosion: Results from the western Gulf of Lions. Cont. Shelf Res. 28(15): 1935-1946.

LeBel, D.A., W.M. Smethie, Jr., M. Rhein, D. Kieke, R.A. Fine, J.L. Bullister, D.-H. Min, W. Roether, R.F. Weiss, C. Andrié, D. Smythe-Wright, and E. P. Jones. 2008. The formation rate of North Atlantic deep water and eighteen degree water calculated from CFC-11 inventories observed during WOCE. Deep-Sea Res. I(55): 891–910.

Leggett, W.C., and K.T. Frank. 2008. Paradigms in fisheries oceanography. Oceanogr. Mar. Biol. Ann. Rev. 46: 331-364.

Li, W.K.W., and W.G. Harrison. 2008. Propagation of an atmospheric climate signal to phytoplankton in a small marine basin. Limnol. Oceanogr. Methods 53: 1734-1745.

Li, W.K.W., M.R. Lewis, and W.G. Harrison. 2008. Multiscalarity of the nutrient-chlorophyll relationship in coastal phytoplankton. Estuar. Coasts. (doi 10.1007/s12237-008-9119-7)

Li, Z., K. Lee, T. King, M.C. Boufadel, and A.D. Venosa. 2008. Assessment of chemical dispersant effectiveness in a wave tank under regular non-breaking and breaking wave conditions. Mar. Pollut. Bull. 56: 903-912.

Lidgard, D.C., D.J. Boness, W.D. Bowen, and J.I. McMillan. 2008. The implications of stress on male mating behavior and success in a sexually dimorphic polygynous mammal, the grey seal. Horm. Behav. 53: 241-248.

Loring, D.H., PA Yeats, and T.G. Milligan. 2008. Sources and distribution of metal contamination in surficial sediments of Sydney Harbour, Nova Scotia. Proc. N.S. Inst. Sci. 44: 153-170.

Ma, X., A. Cogswell, Z. Li, and K. Lee. 2008. Particle size analysis of dispersed oil and oil-mineral aggregates with an automated epifluorescence microscopy system. Environ. Technol. 29(7): 739-748.

Marklevitz, S.A.C., E. Almeida, J. Flemming, and J. Hellou. 2008. Determining the quality of sediments and assessing the bioavailability of contaminants. Part 1. Variables affecting the behavioural response of *Ilyanassa obsolete* towards contaminated harbour sediments. J. Soils Sediments 8(2): 86-91.

Marklevitz, S.A.C., E. Almeida, J. Flemming, and J. Hellou. 2008. Determining the quality of sediments and assessing the bioavailability of contaminants. Part 2. Behavioural response of *Ilyanassa obsolete* towards contaminated harbour sediments. J. Soils Sediments 8(2): 92-97.

Mikkelsen, O.A., T.G. Milligan, P.S. Hill, R.J. Chant, C.F. Jago, S.E. Jones, V. Krivtsov, and G. Mitchelson-Jacob. 2008. The influence of schlieren on *in situ* optical measurements used for particle characterization. Limnol. Oceanogr. Methods 6: 133-143.

Miller, R.J., and S.C. Nolan. 2008. Management methods for a sea urchin dive fishery with individual fishing zones. J. Shellfish Res. 27: 929-938.

Nair, A., S. Sathyendranath, T. Platt, J. Morales, V. Stuart, M.-H. Forget, E. Devred, E., and H. Bouman. 2008. Remote sensing of phytoplankton functional types. Remote Sens. Environ. 112: 3366–3375.

Neilson, J.D., and S.E. Campana. 2008. A validated description of age and growth of western Atlantic bluefin tuna (*Thunnus thynnus*). Can. J. Fish. Aquat. Sci. 65: 1523-1527.

Niu, H., A. Drozdowski, T. Husain, B. Veitch, N. Bose, and K. Lee. 2008. Modeling the dispersion of drilling muds using the bottom boundary layer transport model: The effects of settling velocity. Environ. Model. Assess. (doi:10.1007/s10666-008-9162-6)

Noren, S.R., D.J. Boness, S.J. Iverson, J. McMillan, and W.D. Bowen. 2008. Body condition at weaning affects the duration of the postweaning fast in gray seal pups (*Halichoerus grypus*). Physiol. Biochem. Zool. 81: 269-277.

Padilla, R., W. Perrie, B. Toulany, and P.C. Smith. 2007.* Intercomparison of third generation wave models. Wea. Forecasting 22: 1229-1242.

Pahlow, M., A.F. Vézina, B. Casault, H. Maass, L. Malloch, D.G. Wright, and Y. Lu. 2008. Adaptive model of plankton dynamics for the North Atlantic. Prog. Oceanogr. 76: 151-191. (doi:10.1016/j.pocean.2007.11.001)

Perrie, W., W. Zhang, M. Bourassa, H. Shen, and P. W. Vachon. 2008. Impact of satellite winds on marine wind simulations. Wea. Forecasting 23: 290–303.

Peterson, I.K., S.J. Prinsenberg, and J.S. Holladay. 2008. Observations of sea ice thickness, surface roughness and ice motion in Amundsen Gulf. J. Geophys. Res. 113, C06016. (doi:10.1029/2007JC004456)

Pettigrew, N.R., H. Xue, J.D. Irish, W. Perrie, C.S. Roesler, A.C. Thomas, and D.W. Townsend. 2008. The Gulf of Maine Ocean Observing System: Generic lessons learned in the first seven years of operation (2001-2008). Mar. Technol. Soc. J. 42: 91-102.

* Citation year is 2007; however, publication occurred only after publication of "Bedford Institute of Oceanography 2007 in Review".

Platt, T., and S. Sathyendranath. 2008. Ecological indicators for the pelagic zone of the ocean. Remote Sens. Environ. 112: 3426-3436.

Platt, T., S. Sathyendranath, M.-H. Forget, G.N. White, C. Caverhill, H. Bouman, E. Devred, and S. Son. 2008. Operational mode estimation of primary production at large geographical scales. Remote Sens. Environ. 112: 3437–3448.

Polyakov, I.V., V. Alexeev, G.I. Belchansky, I.A. Dmitrenko, V.A. Ivanov, S. Kirillov, A. Korablev, M. Steele, L. A. Timokhov, and I. Yashayaev . 2008. Arctic Ocean freshwater changes over the past 100 years and their causes. J. Clim. 21(2): 364–384.

Prinsenberg, S.J., I.K. Peterson, and S. Holladay. 2008. Measuring freshwater-layer plume depths and ice thicknesses of and beneath the land-fast ice region of the Mackenzie Delta with Helicopter-borne sensors. J. Mar. Syst., CASES Spec. Issue 74: 783-793. (doi:10.1016/j.jmarsys.2008.02.009)

Resio, D., and W. Perrie. 2008. A two-scale approximation for efficient representation of nonlinear energy transfers in a wind wave spectrum. Part 1: Theoretical Development. J. Phys. Oceanogr. 38: 2801-2816.

Rowe, S., and J.A. Hutchings. 2008. A link between sound producing musculature and mating success in Atlantic cod. J. Fish Biol. 72: 500-511.

Rowe, S., J.A. Hutchings, J.E. Skjæraasen, and L. Bezanson. 2008. Morphological and behavioural correlates of reproductive success in Atlantic cod *Gadus morhua*. Mar. Ecol. Prog. Ser. 354: 257-265.

Ryan, S.A, J.C. Roff, and P.A. Yeats. 2008. Development and application of seasonal indices of coastal-zone eutrophication. ICES J. Mar. Sci. 65: 1469-1474.

Shore, J., M.W. Stacey, and D.G. Wright. 2007.* Energy sources for the eddy field in a numerical simulation of the Northeast Pacific Ocean. J. Phys. Oceanogr. 38(10): 2283-2293.

Stewart, J.E. 2008. Bacterial involvement in determining domoic acid levels in *Pseudo-nitzschia* multiseries cultures. Aquat. Microb. Ecol. 50: 135-144.

Stewart, J.E. 2008. Postconsumption domoic acid generation by the diatom *Pseudo-nitzschia* multiseries as a factor in depuration models. Can. J. Fish. Aquat. Sci. 65: 1797-1799.

Svendsen, T.C., L. Camus, B. Hargrave, A. Fisk, D.C.G. Muir, and K. Borgå. 2007.* Polyaromatic hydrocarbons, chlorinated and brominated organic contaminants as tracers of feeding ecology in polar amphipods. Mar. Ecol. Prog. Ser. 337: 155-164.

Tarrant, A.M., M.F. Baumgartner, T. Verslycke, and C.L. Johnson. 2008. Differential gene expression in diapausing and active *Calanus finmarchicus* (Copepoda). Mar. Ecol. Prog. Ser. 355: 193-207.

Treble, M.A., S.E. Campana, R.J. Wastle, C.M. Jones, and J. Boje. 2008. Growth analysis and age validation of a deepwater Arctic fish, the Greenland halibut (*Reinhardtius hippoglossoides*). Can. J. Fish. Aquat. Sci. 65: 1047-1059.

Tucker, S., W.D. Bowen, and S.J. Iverson. 2008. Convergence of diet estimates from fatty acids and stable isotopes, support for long-term integration of natural diets within individual grey seals. Mar. Ecol. Prog. Ser. 354: 267-276

Våge, K., R.S. Pickart, V. Thierry, G. Reverdin, C.M. Lee, B. Petrie, T.A. Agnew, A.Wong, and M.H. Ribergaard. 2008. Deep convection returns to the subpolar North Atlantic. Nat. Geosci. (doi:10.1038NGEO382)

Walker, T.R., J. Grant, P. Cranford, D.G. Lintern, P. Hill, P. Jarvis, J. Barrell, and C. Nozais. 2008. Suspended sediment and erosion dynamics in Kugmallit Bay and Beaufort Sea during ice-free conditions. J. Mar. Syst. 74: 794-809.

Wu, Y., T. Platt, C.L. Tang, S. Sathyendranath, E. Devred, and S. Gu. 2008. A summer phytoplankton bloom triggered by high wind events in the Labrador Sea, July 2006. Geophys. Res. Lett. 35, L10606: 1-6. (doi:10.1029/2008GL033561)

Wu, Y.S., T. Platt, C.L. Tang, and S. Sathyendranath. 2008. Regional differences in the timing of the spring bloom in the Labrador Sea. Mar. Ecol. Prog. Ser. 355: 9-20.

Yao, Y., W. Perrie, W. Zhang, and J. Jiang. 2008. The characteristics of atmosphere-ocean interactions along North Atlantic extratropical storm tracks. J. Geophys. Res. 113, D14124. 20 p. (doi:10.1029/2007JD008854)

Yashayaev, I., and R. A. Clarke. 2008. Evolution of North Atlantic water masses inferred from Labrador Seas salinity series, pp. 30-45. *In* R. Schmitt and J. Carton [ed.]. Special issue: Salinity. Oceanography 21(1).

Yeats, P., F. Gagne, and J. Hellou. 2008. Body burden of contaminants and biological effects in mussels: an integrated approach. Environ. Int. 34: 254-264.

Yeats, P.A. 2008. Assessment of environmental conditions in Sydney Harbour, Nova Scotia: General introduction. Proc. N.S. Inst. Sci. 44: 149-152.

Yeats, P.A., and J.A. Dalziel. 2008. Heavy metal distributions in the waters of Sydney Harbour, N.S. Proc. N. S. Inst. Sci. 44: 171-186.

Zhai, L., T. Platt, C. Tang, M. Dowd, S. Sathyendranath, and M. H. Forget. 2008. Estimation of phytoplankton loss rate by remote sensing. Geophys. Res. Lett. 35, L23606. 5 p. (doi.10.1029/2008GL035666)

Zhang, W., and W. Perrie. 2008. The influence of air-sea roughness, sea spray and storm translation speed on waves. J. Phys. Oceanogr. 38: 817–839.

Zhao, L., Z. Chen, and K. Lee. 2008. A risk assessment model for produced water discharge from offshore petroleum platforms-development and validation. Mar. Pollut. Bull. 56: 1890–1897.

* Citation year is 2007; however, publication occurred only after publication of "Bedford Institute of Oceanography 2007 in Review".

NRCan

Anderson, J., S. Adams, R. Lewis, C. Lang, N. Ollerhead, D. Holloway and J. Shaw. 2008. Acoustic seabed classification of habitats using an Autonomous Underwater Vehicle. Abstract, Lighthouse, Journal of the Canadian Hydrographic Association, 72 Spring/Summer 2008, p. 40 and 69.

Croley II, T.E. and C.F.M. Lewis. 2008. Warmer and drier climates that make Lake Huron into a terminal lake. Aquatic Ecosystem Health & Management. 11(2), 153-160.

Deptuck, M.E., D.J.W. Piper, B. Savoye and A. Gervais. 2008. Dimension and architecture of Late Pleistocene submarine lobes off the northern margin of east Corsica. Sedimentology, 55, 869-898.

Giles, P.S. 2008. Windsor Group (Late Mississippian) stratigraphy, Magdalen Islands, Québec: a rare eastern Canadian record of Late Visean basaltic volcanism. Atlantic Geology, 44, 167-185.

Greenan, B., M. Nedimovic, K. Louden, R. Mirshak, B. Ruddick and J. Shimeld. 2008. ROSE - Reflection Ocean Seismic Experiment. Canadian Meteorological and Oceanographic Society Bulletin, 36(2), 43-50.

Hundert, T. and D.J.W. Piper. 2008. Late Quaternary sedimentation on the southwestern Scotian Slope, eastern Canada: relationship to glaciation. Canadian Journal of Earth Sciences, 45, 267-285.

Lewis, C.F.M., P.F. Karrow, S.M. Blasco, F.M.G. McCarthy, J.W. King, T.C. Moore and D.K. Rea. 2008. Evolution of lakes in the Huron basin: Deglaciation to present. Aquatic Ecosystem Health & Management. 11(2), 127-136.

Lewis, C.F.M., J.W. King, S.M. Blasco, G.R. Brooks, J.P. Coakley, T.E. Corley II, D.L. Dettman, T.W.D. Edwards, C.W. Heil Jr., J.B. Hubeny, K.R. Laird, J.H. McAndrews, F.M.G. McCarthy, B.E. Medioli, T.C. Moore Jr., D.K. Rea and A.J. Smith. 2008. Dry climate disconnected the Laurentian Great Lakes. EOS Transactions of the American Geophysical Union. 90(52), 541-542.

Longva, O., H.A. Olsen, D.J.W. Piper, L. Rise and T. Thorsnes. 2008. Late glacial fans in the eastern Skagerrak: depositional environment interpreted from swath bathymetry and seismostratigraphy. Marine Geology, 251, 110-123.

Mosher, D.C., J.A. Austin, D. Fisher and S.P.S. Gulick. 2008. Deformation of the northern Sumatra accretionary prism from high-resolution seismic reflection profiles and ROV observations. Marine Geology, 252, 89-99, Doi: 10.1016/j.margeo.2008.03.014.

Parrott, D.R., B.J. Todd, J. Shaw, J.E. Hughes-Clarke, J. Griffin, B. MacGowan, M. Lamplugh and T. Webster. 2008. Integration of multibeam bathymetry and LiDAR surveys of the Bay of Fundy, Canada. Abstract, Lighthouse, Journal of the Canadian Hydrographic Association, 72 Spring/Summer 2008, p.36 and 63.

Pe-Piper, G., S. Triantafyllidis and D.J.W. Piper. 2008. Geochemical identification of clastic sediment provenance from known sources of similar geology: the Cretaceous Scotian Basin, Canada. Journal of Sedimentary Research, 78, 595-607.

Piper, D.J.W., G. Pe-Piper and S. Ledger-Piercey. 2008. Geochemistry of the Lower Cretaceous Chaswood Formation, Nova Scotia, Canada; provenance and diagenesis. Canadian Journal of Earth Sciences, 45, 1083-1094.

Shaw, J., G. Duffy, R.B. Taylor, J. Chassé and D. Frobel. 2008. Role of a submarine bank in the evolution of the northeast coast of Prince Edward Island, Canada. Journal of Coastal Research, 24(5), 1249-1259.

Shaw, J., G.B.J. Fader and R.B. Taylor. 2008. Submerged early-Holocene coastal and terrestrial landforms on the inner shelves of Atlantic Canada. Quaternary International.

Shaw, J. 2008. Application of multibeam bathymetry to geological mapping. Abstract, Lighthouse, Journal of the Canadian Hydrographic Association, 72 Spring/Summer 2008, p.39 and 67.

Stevens, C.W., B.J. Moorman, S.M. Solomon, and C.H. Hugenholtz. 2008. Mapping subsurface conditions within the nearshore zone of an Arctic delta using ground penetrating radar. Cold Regions Science and Technology, 56, 30-38.

Todd, B.J., C.F.M. Lewis, and T.W. Anderson. 2008. Quaternary features beneath Lake Simcoe, Ontario, Canada: drumlins, tunnel channels, and records of postglacial closed and overflowing lakes. Journal of Paleolimnology. 39, 361-380.

Tripsanis, E., D.J.W. Piper, K.A. Jenner and W.R. Bryant. 2008. Sedimentary characteristics of submarine mass-transport deposits: New perspectives from a core-based facies classification. Sedimentology, 55, 97-136.

Tripsanis, E., D.J.W. Piper and D.C. Campbell. 2008. Evolution and depositional structure of earthquake-induced mass movements and gravity flows, southwest Orphan Basin, Labrador Sea. Marine and Petroleum Geology, 25, 645-662.

Tripsanis E.K. and D.J.W. Piper. 2008. Late Quaternary stratigraphy and sedimentology of Orphan Basin: implications for meltwater dispersal in the southern Labrador Sea. Palaeogeography, Palaeoclimatology, Palaeoecology, 260, 521-539.

Tripsanis, E.K. and D.J.W. Piper. 2008. Late Quaternary glacigenic debris flows in Orphan Basin. Journal of Sedimentary Research . 78, 713-723.

Tsikouras, B., G. Pe-Piper, D.J.W. Piper and K. Hatzipanagiotou. 2008. Triassic rift-related komatite, picrite and basalt, Pelagonian continental margin, Greece. Lithos, 104, 199-215.

Utting, J. and P.S. Giles. 2008. Palynostratigraphy and lithostratigraphy of Carboniferous Upper Codroy Group and Barachois Group, southwestern Newfoundland. Canadian Journal of Earth Sciences, 45, 45-67.

* Citation year is 2007; however, publication occurred only after publication of "Bedford Institute of Oceanography 2007 in Review".

Wallace, P., P. Potter and J. Shimeld. 2008. Using a modified Hele-Shaw cell to understand the layering of strata. Journal of Geoscience Education, 56(2), 172-178.

Winch, S., D. Fortin, D.R.S. Lean and M.B. Parsons. 2008. Factors affecting methylmercury levels in surficial tailings from historical Nova Scotia gold mines. Geomicrobiology Journal, 25, 112-129.

BOOKS; BOOK CHAPTERS:

DFO: Science Branch

Chen, Z., C.S. Zhan, K. Lee, Z. Li, and M.C. Boufadel. 2008. Modeling of oil droplet kinetics under breaking waves, p. 221-236. *In* W.F. Davidson, K. Lee, and A. Cogswell [ed.]. Oil Spill Response: A Global Perspective. Springer Netherlands

Jones, E.P., and L.G. Anderson. 2008. Is the global conveyor belt threatened by Arctic Ocean fresh water outflow?, p. 385-404. *In* R. Dickson, J. Meincke, and P. Rhines. Arctic-Subarctic Ocean Fluxes. Defining the Role of Northern Seas in Climate. Springer, New York.

Kostylev, V.E., and C.G. Hannah. 2007.* Process-driven characterization and mapping of seabed habitats, p. 171 184. *In* B.J.Todd, and H.G. Greene [ed.]. Mapping the Seafloor for Habitat Characterization. Geol. Assoc. Canada, Spec. Pap. 47.

Lee, K., Z. Li, T. King, P. Kepkay, M.C. Boufadel, and A.D. Venosa. 2008. Wave tank studies on formation and transport of OMA from the chemically dispersed oil, p. 159-177. *In* W.F. Davidson, K. Lee, and A. Cogswell [ed.]. Oil Spill Response: A Global Perspective. Springer Netherlands.

Li, Z., K. Lee, P.E. Kepkay, T. King, C.W. Yeung, M.C. Boufadel, and A.D. Venosa. 2008. Wave tank studies on chemical dispersant effectiveness: Dispersed oil droplet size distribution, p. 143-157. *In* W.F. Davidson, K. Lee, and A. Cogswell [ed.]. Oil Spill Response: A Global Perspective. Springer Netherlands.

Melling, H., T. Agnew, K. Falkner, D. Greenberg, C. Lee, A. Münchow, B. Petrie, S. Prinsenberg, R. Samelson, and R. Woodgate. 2008. Fresh-water fluxes via Pacific and Arctic outflows across the Canadian Polar Shelf, p. 193-248. *In* R. Dickson, J. Meincke, and P. Rhines. Arctic-Subarctic Ocean Fluxes. Defining the Role of Northern Seas in Climate. Springer, New York.

Peterson, I., S. Prinsenberg, J. Hamilton, and R. Pettipas. 2008. Variability of oceanographic and ice properties of the Canadian Arctic Archipelago. International Council for the Exploration of the Sea Annual Meeting (September 22-26, 2008, Halifax, Canada). Int. Counc. Explor. Sea. C.M.2008/B:16. 14 p.

Roach, S., B. MacDonald, and E. Kenchington. 2008. North American jackknife and razor clam fisheries, p. 379-390. *In* A. Guerra Díaz y C. Lodeiros Seijo [ed.]. Navajas y longueirones : Biología, pesquerías y cultivo. Consellería de Pesca y Asuntos Marítimos.

Venosa, A.D., K. Lee, Z. Li, and M.C. Boufadel. 2008. Dispersant research in a specialized wave tank: Mimicking the mixing energy of natural sea states, p. 141-142. *In* W.F. Davidson, K. Lee, and A. Cogswell [ed.]. Oil Spill Response: A Global Perspective. Springer Netherlands.

Yashayaev, I., and R. R. Dickson. 2008. Transformation and fate of overflows in the northern North Atlantic, p. 505-526. *In* R. Dickson, J. Meincke, and P. Rhines. Arctic-Subarctic Ocean Fluxes. Defining the Role of Northern Seas in Climate. Springer, New York. (doi: 10.1007/978-1-4020-6774-7_22)

Yashayaev, I., N.P. Holliday, M. Bersch, and H.M. van Aken. 2008. The history of the Labrador Sea water: Production, spreading, transformation and loss, p. 569-612. *In* R. Dickson, J. Meincke, and P. Rhines. Arctic-Subarctic Ocean Fluxes. Defining the Role of Northern Seas in Climate. Springer, New York. (doi: 10.1007/978-1-4020-6774-7_25)

NRCan

Todd, B.J. and H.G. Greene (Eds.). 2007. Mapping the Sea floor for Habitat Characterization. Geological Association of Canada, St. John's, Newfoundland, Special Paper 47, 519 p.

PROCEEDINGS:

DFO: Science Branch

Boufadel, M.C., E. Wickley-Olsen, T. King, Z. Li, K. Lee, and A.D. Venosa. 2008. Theoretical foundation for predicting dispersant effectiveness due to waves, p. 509-514. *In* Proceedings of the International Oil Spill Conference (Savannah, Georgia, U.S.A., May 4-8, 2008).

Guo, J., Y. He, and W. Perrie. 2008. Wave parameters estimated from scatterometer data, p. iv-1414 to iv-1417. *In* International Geoscience and Remote Sensing Symposium (IGARSS) Proc.

Hodson, P.V., C.W. Khan, G. Saravanabhavan, L. Clarke, R.S. Brown, B. Hollebone, Z. Wang, J. Short, K. Lee, and T. King. 2007.* Alkyl PAH in crude oil cause chronic toxicity to early life stages of fish, p. 291-299. *In* Proceedings of the 30th Arctic and Marine Oilspill Program (AMOP) Technical Seminar, Environment Canada (Edmonton, AL, June 4-7, 2007).

Husain, T., B. Veitch, K. Hawboldt, H. Niu, S. Adams, and J. Shanaa. 2008. Produced water discharge monitoring, Paper OTC 19271, p. 1-10. *In* Proceedings of the Offshore Technology Conference (Houston, TX, May 5-8, 2008).

Kepkay, P., Yeung, C.W., Bugden, J.B.C., Li, Z., and Lee, K. 2008. Ultraviolet Fluorescence Spectroscopy (UVFS): A New Means of Determining the Effect of Chemical Dispersants on Oil Spills, p. 639-644. *In* Proceedings of the International Oil Spill Conference (Savannah, Georgia, U.S.A., May 4-8, 2008).

Lee, K., Z. Li, P. Kepkay, M.C. Boufadel, and A.D. Venosa. 2008. Effects of chemical dispersants on oil-mineral-aggregation in a wave tank, p. 633-638. *In* Proceedings of the International Oil Spill Conference (Savannah, Georgia, U.S.A., May 4-8, 2008).

Li, Z., K. Lee, P. Kepkay, M.C. Boufadel, and A.D. Venosa. 2008. Chemical dispersant effectiveness: droplet size distribution as a function of energy dissipation rate, p. 621-626. *In* Proceedings of the International Oil Spill Conference (Savannah, Georgia, U.S.A., May 4-8, 2008).

MacAulay, P.N., C. O'Reilly, and K. Thompson. 2008. Atlantic Canada's real-time water level system observations, predictions, forecasts and datums on the web. *In* Proceedings of the Canadian Hydrographic Conference and National Surveyors Conference 2008. Victoria, B.C., May 5-8, 2008.

MacDougall, J.R., J. Verhoef, W. Sanford, and C. Marcussen. 2008. Challenges of collecting data for Article 76 in ice covered waters of the Arctic. Fifth Conference of the Advisory Board on the Law of the Sea. Monaco, October 16-17, 2008.

MacDougall, J.R., W. Sanford, and J. Verhoef. 2008. Ice and no ice: The Canadian United Nations Convention of the Law of the Sea (UNCLOS) bathymetric mapping program. *In* Proceedings of the Canadian Hydrographic Conference and National Surveyors Conference 2008. Victoria, B.C., May 5-8, 2008.

Niu, H., S. Adams, T. Husain, N. Bose, and K. Lee. 2007.* The application of Autonomous Underwater Vehicles in offshore environmental effect monitoring, Paper 2007-116, p. 1-6. *In* Proceedings of the 2007 Canadian International Petroleum Conference, Canada (Calgary, AB, June 12-14, 2007).

Niu, H., T. Husain, B. Veitch, N. Bose, S. Adams, M. He, and K. Lee. 2007.* Ocean outfall mapping using an Autonomous Underwater Vehicle, Paper 0-933957-35-1, p. 1-4. *In* Proceedings of the MTS/IEEE-OES Conference - Oceans 2007, Canada (Vancouver, BC, September 29-Oct 4, 2007). (doi:10.1109/OCEANS.2007.4449238)

Ohashi, K., J. Sheng, K.R. Thompson, C.G. Hannah, and H. Ritchie. 2008. The effect of stratification on the tidal circulation over the Scotian Shelf and the Gulf of St. Lawr nce: A numerical study, p. 57-73. *In* M.L. Spaulding [ed.]. Estuarine and Coastal Modelling: Proceedings of the 10th International Conference. Am. Soc. Civil Engineers Press, September 2008. 1058 pages.

Prinsenberg, S.J., and R. Pettipas. 2008. Ice and ocean mooring data statistics from Barrow Strait, the central section of the NW Passage in the Canadian Arctic Archipelago, p. 618-623. *In* Proc. of the Eighteenth (2008) International Offshore and Polar Engineering Conference (Vancouver, Canada, July 6-11, 2008) I.

Varma, H., C. Hannah, R. MacNab, G. Costello, T. Spears, W. Woodford, and C. Delbridge. 2008. The complexities in the design and definitions of the north west Atlantic data set: Searching for rational architecture to implement diverse bathymetric data. *In* Proceedings of the Canadian Hydrographic Conference and National Surveyors Conference 2008. Victoria, B.C., May 5-8, 2008. 33 p.

Venosa, A.D., K. Lee, M.C. Boufadel, and Z. Li. 2008. Dispersant effectiveness as a function of energy dissipation rate in a wave tank, p. 777-784. *In* Proceedings of the International Oil Spill Conference (Savannah, Georgia, U.S.A., May 4-8, 2008).

Wickley-Olsen, E., M.C. Boufadel, T. King, Z. Li, K. Lee, and A.D. Venosa. 2008. Regular and breaking waves in wave tank for dispersion effectiveness testing, p. 499-506. *In* Proceedings of the International Oil Spill Conference (Savannah, Georgia, U.S.A., May 4-8, 2008).

Xu, F., and W. Perrie. 2008. Spectral properties of cyclone-generated waves in deep and shallow water, p. 1-8. *In* Proc. of the ASME 27th International Conference on Offshore Mechanics and Arctic Engineering OMAE2008 (June 15-20, Estoril, Portugal). (Available on line at http://www.ooae.org/omaedatabase/omae08dbom.htm)

Zhao, L., Z. Chen, and K. Lee. 2007.* Integrated modeling and risk assessment for the management of produced water discharges, Paper 581-156, p. 440-444. *In* Proceedings of the 16th IASTED (International Association of Science and Technology for Development) International Conference on "Applied Simulation and Modeling" (ASM 2007) (Palma de Mallorca, Spain, August 29–31, 2007).

NRCan

Adam, J., J. Shimeld, C. Krezsek and D. Grujic. 2008. Interplay of salt tectonics and sedimentation in the dynamic depositional systems of the Mesozoic Scotian Margin salt basins and their deepwater extensions, offshore Nova Scotia. In: Offshore Technology Conference, Program with Abstracts, Houston.

Albertz, M., C. Beaumont, S. Ings, S. Gradmann and J. Shimeld. 2008. Structural styles related to salt tectonics in the Scotian Basin, eastern Canada. In: PETEX 2008, Program with Abstracts, Petroleum Exploration Society of Great Britain, London.

Anderson, J., S. Adams, R. Lewis, C. Lang, N. Ollerhead, D. Holloway and J. Shaw. 2008. Acoustic seabed classification of habitats using an Autonomous Underwater Vehicle. Canadian Hydrographic Conference, Victoria, BC, Poster..

Brake, V.I., D.C. Mosher and G. Wach. 2008. Oligocene canyon and fan development: the respective roles of sea level and sediment delivery in evolution of the eastern Scotian margin. Extended Abstract, Proceedings of the Canadian Society of Petroleum Geologists Joint Annual Convention, May 12-15, 2008, Calgary, Alta, Abstract 122, p. 77-79.

Brake, V., D.C. Mosher and G. Wach. 2008. Oligocene canyon development: implications for sediment delivery on the eastern Scotian Margin. In: (D. Brown and N. Watson, eds). Extended Abstract, Proceedings and Poster, Central Atlantic Conjugate Margins Conference, Halifax, Nova Scotia, August 13-15, 2008, p. 366-370.

* Citation year is 2007; however, publication occurred only after publication of "Bedford Institute of Oceanography 2007 in Review".

Brown, D.E., S.A. Dehler, K. Louden and Y. Wu. 2008. The Early Jurassic Heracles sequence, Scotian Basin, Canada: recognition of a latest stage synrift/pre-breakup tectonic and sedimentary event. Atlantic Geoscience Society Annual Meeting, Halifax, NS, February 2008.

Cassidy, J.F., H. Kao, H. Kim, S. Dehler, S. Dosso and J. Halliday. 2008. Mapping sedimentary basins across Canada using receiver function analysis. American Geophysical Union Annual Fall Meeting, San Francisco, CA, December 2008.

Cullen, J., D.C. Mosher and K. Louden. 2008. The Mohican Channel gas hydrate zone, Scotian Slope: geophysical structure. Proceedings of the 6th International Conference on Gas Hydrates (ICGH2008), Vancouver, British Columbia, Canada, July 6-10, 2008, 10 p.

Dahl-Jensen, T., H.R. Jackson, D. Chian, J. Shimeld and G. Oakey. 2008. Crustal structure from the Lincoln Sea to the Lomonosov Ridge, Arctic Ocean. In: 33rd International Geological Congress, Abstracts, International Union of Geological Sciences, Oslo.

Dehler, S.A. and J.K. Welford. 2008. Variations in crustal thickness and extensional style along the Scotian margin, Atlantic Canada; constraints from seismic data and 3D gravity inversion. Central Atlantic Conjugate Margins Conference, Halifax, NS, August 2008.

Dinkelman, M.G. and J.W. Shimeld. 2008. The NovaSpan Project: deep imaging of an enigmatic conjugate margin. In: Central Atlantic Conjugate Margins Conference, Program with Abstracts, Offshore Energy Technical Research Association, Halifax.

Goss, S., D.C. Mosher and G. Wach. 2008. Continental margin development of the equatorial gateway, Suriname, South America. In: (D. Brown and N. Watson, eds) Extended Abstract Proceedings and Poster, Central Atlantic Conjugate Margins Conference, Halifax, Nova Scotia, August 13-15, 2008, p. 282-291.

Hoque, M.A., S.M. Solomon, W. Perrie, B. Tounaly and R. Muligan. 2008. Modelling Beaufort Sea wave conditions under severe Arctic storms. Arctic Changes Conference, Québec, Canada, December 9-12, 2008.

Li, M.Z., Q. Zou, C. Hannah, W. Perrie, R. Prescott and B. Toulany. 2008. Numerical modelling of seabed disturbance and sediment mobility and implications to morphodynamics on the storm dominated Sable Island Bank, Scotian Shelf. Program with Abstracts, 2008 Ocean Sciences Meeting, Orlando.

Lyon, S.A., S.M. Barr and S.A. Dehler. 2008. Sources of magnetic and gravity anomalies on the Scotian Shelf southeast of Cape Breton Island, Nova Scotia, and onshore-offshore geological correlations using geophysical modelling. Atlantic Geoscience Society Annual Meeting, Halifax, NS, February 2008.

MacLean, B., S. Blasco, R. Bennett, W. Rainey, J. Hughes-Clarke and J. Beaudoin. 2008. Glacial flute marks and iceberg scours inscribed on the seabed in Peel Sound, Franklin Strait, Larsen Sound, and M'Clintock Channel, Canadian Arctic Archipelago. Conference Program and Abstracts, Arctic Change Conference 2008, December 9-12, Quebec City, p. 267-268.

Mirshak, R., M. Nedimovic, B. Greenan, K. Louden, B. Ruddick and J. Shimeld. 2008. Comparison of field and synthetic seismic reflection images of Gulf Stream and Slope waters southeast of Nova Scotia. In: European Geosciences Union General Assembly, Geophysical Research Abstracts, European Geosciences Union, Vienna.

Mirshak, R., M. Nedimovic, B. Greenan, K. Louden, B. Ruddick and J. Shimeld. 2008. ROSE: Coincident seismic and hydrographic survey of the Gulf Stream and slope waters southeast of Nova Scotia. In: European Geosciences Union General Assembly, Geophysical Research Abstracts, European Geosciences Union, Vienna.

Mosher, D.C. 2008. Bottom simulating reflectors on Canada's East Coast margin: evidence for gas hydrate. Proceedings of the 6th International Conference on Gas Hydrates (ICGH2008), Vancouver, British Columbia, Canada, July 6-10, 2008, 10 p.

Mosher, D.C. 2008. Submarine mass-movements in Canada: geohazards with far reaching implications (invited). Comptes rendus de la 4e Conférence canadienne sur les géorisques: des causes à la gestion. Proceedings of the 4th Canadian Conference on Geohazards: from causes to management. Presse de l'Université Laval, Quebec. p.55-62.

Nedimovic, M.R., B.J.W. Greenan, K.E. Louden, B.R. Ruddick, R. Mirshak and J.W. Shimeld. 2008. ROSE: Coincident seismic and hydrographic survey of the Gulf Stream and slope waters southeast of Nova Scotia. In: Ocean Sciences Meeting, Program with Abstracts, Orlando, Florida.

Pe-Piper, G. and D.J.W. Piper. 2008. Field Trip 3: onshore equivalents of the Cretaceous reservoir rocks of Scotian Basin: detrital petrology, tectonics, and diagenesis. Central Atlantic Conjugate Margins Conference, Halifax, August 13-15, 2008, 45 p.

Rowlands, R., R. Jackson and J. Shimeld. 2008. Operational factors affecting an UNCLOS seismic survey on an ice-covered extended continental shelf. In: 33rd International Geological Congress, Abstracts, International Union of Geological Sciences, Oslo.

Shaw, J. 2008. Application of multibeam bathymetry to geological mapping. Canadian Hydrographic Conference, Victoria, BC.

Shimeld, J., R. Jackson, K. DesRoches and J. Verhoef. 2008. 2007 deep-water marine seismic acquisition to define the Canadian extended continental shelf under Article 76 of the United Nations Convention on the Law of the Sea. In: 34th Annual Colloquium, Program with Abstracts, Atlantic Geoscience Society, Halifax.

Solomon, S., D.L. Forbes, P. Fraser, B. Moorman, C.W. Stevens and D. Whalen. 2008. Nearshore geohazards in the southern Beaufort Sea, Canada. International Pipeline Conference, September 29 - October 3, 2008, Calgary, Alberta.

Solomon, S.M., A.E. Taylor and C.W. Stevens. 2008. Nearshore ground temperatures, seasonal ice bonding and permafrost formation within the bottom-fast ice zone, Mackenzie Delta, NWT. Ninth International Conference on Permafrost, June 2008, Fairbanks, Alaska.

Stevens, C.W., B.J. Moorman, ans S.M. Solomon. 2008. Detection of frozen and unfrozen interfaces with ground penetrating radar in the nearshore zone of the Mackenzie Delta, Canada. Ninth International Conference on Permafrost, June 2008, Fairbanks, Alaska.

* Citation year is 2007; however, publication occurred only after publication of "Bedford Institute of Oceanography 2007 in Review".

Taylor, R.B., D.L. Forbes, D. Frobel, G. Manson, S. Solomon, and D. Whalen. 2008. Monitoring and Assessing coastal change in the Canadian Arctic, Abstracts Volume, 2nd IPY Workshop on Sustaining Arctic Observation Networks in Edmonton, Alberta, April 9-11, 2008.

DEPARTMENTAL REPORTS:

DFO: Oceans, Habitat and Species at Risk Branch

Government of Canada (2007). *Eastern Scotian Shelf Integrated Ocean Management Plan: Strategic Plan.* Oceans and Habitat Branch, Fisheries and Oceans Canada. DFO/2007-1229.

Government of Canada (2007). *Eastern Scotian Shelf Integrated Ocean Management Plan: Summary.* Oceans and Habitat Branch, Fisheries and Oceans Canada. DFO/2007-1228.

Government of Canada (2007). *Eastern Scotian Shelf Integrated Ocean Management Plan: Strategic Plan.* Oceans and Habitat Branch, Fisheries and Oceans Canada. DFO/2007-1229.

Government of Canada (2007). *Eastern Scotian Shelf Integrated Ocean Management Plan: Summary.* Oceans and Habitat Branch, Fisheries and Oceans Canada. DFO/2007-1228.

DFO: Science

Cullen J., A. Hay, H. Ritchie, S. Hartwell, S. Kirchhoff, T. Bowen, M. Dowd, B. Greenan, J. Hamilton, C. Hannah, M. Lewis, W. Perrie, J. Sheng, P. Smith, H. Thomas, and A. Vézina. 2008. The Lunenburg Bay project. Can. Meteorol. Oceanogr. Soc. Bull. 36: 199-205.

DFO AZMP Monitoring Group. 2008. Environmental review: Physical, chemical, and biological status of the environment. Atl. Zone Monit. Progr. Bull. 7: 3-11.

Gjerdrum, C., E.J.H. Head, and D.A. Fifield. 2008. Monitoring seabirds at sea in eastern Canada. Atl. Zone Monit. Progr. Bull. 7: 52-59.

Gordon, D.C., Jr., E.L.R. Kenchington, K.D. Gilkinson, G.B.J. Fader, C. Bourbonnais-Boyce, K.G. MacIsaac, D.L. McKeown, L.-A. Henry, and W.P. Vass. 2008. Summary of the Western Bank otter trawling experiment (1997-1999): Effects on benthic habitat and communities. Can. Tech. Rep. Fish. Aquat. Sci. 2822. 75 p.

Greenan, B., M. Nedimovic, K. Louden, R. Mirshak, B. Ruddick, and J. Shimeld. 2008. ROSE – Reflection Ocean Seismic Experiment. Can. Meteorol. Oceanogr. Soc. Bull. 36: 43-50.

Hamilton, J., R. Pettipas, and S. Prinsenberg. 2008. Moored current meter and CTD observations from Barrow Strait, 2003-2004. Can. Data Rep. Hydrogr. Ocean Sci. 173: vii + 134 p.

Hannah, C.G., F. Dupont, A.K. Collins, M. Dunphy, and D. Greenberg. 2008. Revisions to a modelling system for tides in the Canadian Arctic Archipelago. Can. Tech. Rep. Hydrogr. Ocean Sci. 259: vi + 62 p. (Available on line at www.dfo-mpo.gc.ca/Library)

Head, E.J.H. and P. Pepin. 2008. Seasonal cycles of *Calanus finmarchicus* abundance at fixed time series stations on the Scotian and Newfoundland shelves. Atl. Zone Monit. Progr. Bull. 7: 17-20.

Johnson, C.J., A.W. Leising, J.A. Runge, E.J.H. Head, P. Pepin, S. Plourde, and E.G. Durbin. 2008. Understanding copepod life history patterns through inter-regional comparison of AZMP zooplankton data. Atl. Zone Monit. Progr. Bull. 7: 21-26.

King, T.L., and K. Lee. 2008. Rapid extraction of chlorobiphenyls from sediment grab samples using a ball-mill extractor. Can. Tech. Rep. Fish. Aquat. Sci. 2804: v + 20 p.

McLaughlin, F.A., M.B. Yunker, F.A. Whitney, K. Lee, B.R. Fowler, M.G. Fowler, and R. Robinson. 2008. Hydrocarbon and hydrographic data from southern Hecate Strait: Water and sediment samples collected in September, 2003. Can. Data Rep. Hydrogr. Ocean Sci. 168: vi + 118 p.

Pettipas, R., J. Hamilton, and S. Prinsenberg. 2008. Moored current meter and CTD observations from Barrow Strait, 2004-2005. Can. Data Rep. Hydrogr. Ocean Sci. 174: vii + 135 p.

Ryan, J. [ed.]. 2008. Bedford Institute of Oceanography 2007 in review. Natural Resources Canada and Fisheries and Oceans Canada. 96 p.

Tang, C.L., T. Yao, W. Perrie, B.M. DeTracey, B. Toulany, E. Dunlap, Y. Wu. 2008. BIO ice-ocean and wave forecasting models and systems for Eastern Canadian waters. Can. Tech. Rep. Hydrogr. Ocean Sci. 261: iv + 60 p.

Tremblay M.J., G.A.P. Black, and R.M. Branton. 2007.* The distribution of common decapod crustaceans and other invertebrates recorded in annual ecosystem surveys of the Scotian Shelf 1999-2006. Can. Tech. Rep. Fish. Aquat. Sci. 2762: iii + 74 p.

NRCan

Dehler, S.A. 2008. Searching for petroleum resources in offshore Atlantic Canada. NRCan Making a Difference 004, 2 p.

Dehler, S.A. 2008. A la recherché de resources pétrolières au large des cotes canadiennes de l'Atlantique. NRCan Making A Difference 004, 2 p.

Geological Survey of Canada Open File Reports

Avery, M.P. 2008. Vitrinite reflectance data for Chevron et al Hopedale E-33. Geological Survey of Canada Open File 5669, 8 p.

Avery, M.P. 2008. Vitrinite reflectance data for Petro Canada - Mobil Hesper I-52. Geological Survey of Canada Open File 5670, 10 p.

Bennett, R., A. Rochon, T. Schell, S. Blasco, J. Hughes-Clarke, D. Scott, A. MacDonald, W. Rainey. 2008. Cruise Report Amundsen 2004-804: Beaufort Sea/Amundsen Gulf/Northwest Passage, June 23 - August 27, 2004. Geological Survey of Canada Open File 5798, 111 p.

Bennett, R., A. Rochon, T. Schell, J. Beaudoin, S. Blasco, J. Hughes-Clarke, J. Bartlett. 2008. Cruise Report Amundsen 2005-804: Beaufort Sea/Amundsen Gulf/Northwest Passage, August 5 - September 15, 2005. Geological Survey of Canada Open File 5797, 75 p.

Karim, A., G. Pe-Piper and D.J.W. Piper. 2008. Distribution of diagenetic minerals in Lower Cretaceous sandstones and their relationship to stratigraphy and lithofacies: Glenelg, Thebaud and Chebucto fields, offshore Scotian Basin. Geological Survey of Canada Open File 5880, 423 p.

Parrott, D.R., B.J. Todd, J. Shaw, J. Griffin, J.E. Hughes-Clarke and T. Webster. 2008. Sun-illuminated seafloor topography, Bay of Fundy, offshore Nova Scotia. Geological Survey of Canada Open File, scale 1:50,000, 1 sheet.

Shimeld, J. 2008. Seismic data recording and processing. In: H. Jackson, ed., field report for 2007 the CCGS Louis S. St-Laurent seismic cruise to the Canada Basin. Geological Survey of Canada Open File 5818.

Taylor, R.B., D. Frobel and D. Mercer. 2008. Impacts of post-tropical storm Noel (November 2007) on the Atlantic coastline of Nova Scotia. Geological Survey of Canada Open File 5802, 90 p.

Taylor, R.B., E. Patton and D. Frobel. 2008. Historical changes in Cow Bay Beach, Halifax Regional Municipality, Nova Scotia. Geological Survey of Canada Open File 5902; poster CD-ROM, conference abstract.

Geological Survey of Canada Maps

Shaw, J. And D.P. Potter. 2008. Surficial geology and sun-illuminated seafloor topography, Great Bras d'Or, Cape Breton Island, Nova Scotia. Geological Survey of Canada Map 2116A, scale 1:50,000.

Shaw, J. and D.P. Potter. 2008. Surficial geology and sun-illuminated seafloor topography, Bras d'Or Lake, Cape Breton Island, Nova Scotia. Geological Survey of Canada Map 2105A, scale 1:50,000.

SPECIAL PUBLICATIONS:

Amiro, P.G. 2008. A proposal for status indicators, status classifications and management actions for Atlantic salmon populations in the Maritimes Region. DFO Can. Sci. Advis. Sec. Res. Doc. 2008/068. vi + 26 p.

Amiro, P.G., J.C. Brazner, and J.L. Giorno. 2008. Assessment of the recovery potential for the Atlantic salmon designatable unit for the inner Bay of Fundy: Habitat Issues. DFO Can. Sci. Advis. Sec. Res. Doc. 2008/058: iv + 17 p.

Amiro, P.G., J.C. Brazner, and J.L. Giorno. 2008. Assessment of the recovery potential for the Atlantic salmon designatable unit inner Bay of Fundy: Threats. DFO Can. Sci. Advis. Sec. Res. Doc. 2008/059. v + 42 p.

Boessenkool, K.P., I.R. Hall, H. Elderfield, and I. Yashayaev. 2008. Deep ocean flow speed linked to NAO through Labrador Sea convection. PAGES (Past Global Changes) News 16(1): 32-33.

Bowen, W.D., J.I. McMillan, D. Lidgard, and W. Blanchard. 2007.* Continued reduction in population growth rate of grey seals at Sable Island. DFO Can. Sci. Advis. Sec. Res. Doc. 2007/087. iii + 16 p.

Busby, C.D., M.J. Morgan, K.S. Dwyer, G.M. Fowler, R. Morin, M. Treble, D.M. Parsons, and D. Archambault. 2007.* Review of the structure, the abundance and distribution of American plaice (*Hippoglossoides platessoides*) in Atlantic Canada in a species-at-risk context. DFO Can. Sci. Advis. Sec. Res. Doc. 2007/69: iv + 90 p.

Campana, S.E., A.J.F. Gibson, L. Marks, W. Joyce, R. Rulifson, and M. Dadswell. 2007.* Stock structure, life history, fishery and abundance indices for spiny dogfish (*Squalus acanthias*) in Atlantic Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2007/089. iv + 132 p

Campana, S.E., J. Gibson, J. Brazner, L. Marks, W. Joyce, J.-F. Gosselin, R.D. Kenney, P. Shelton, M. Simpson, and J. Lawson. 2008. Status of basking sharks in Atlantic Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2008/004. vi + 61 p.

Choi, J.S., and B.M. Zisserson. 2008. An assessment of the snow crab resident on the Scotian Shelf in 2006, focusing upon CFA 4X. DFO Can. Sci. Advis. Sec. Res. Doc. 2008/003. ii + 81 p.

Yeats, P., J. Hellou, T. King, and B. Law. 2008. Measurements of chemical contaminants and toxicological effects in the Gully. DFO Can. Sci. Advis. Sec. Res. Doc. 2008/066. iv + 21 p.

Choi, J.S., B.M. Zisserson, and P. Kuhn. 2008. Integrated assessment of the snow crab resident on the Scotian Shelf in 2007. DFO Can. Sci. Advis. Sec. Res. Doc. 2008/012. iv + 92 p.

---

* Citation year is 2007; however, publication occurred only after publication of "Bedford Institute of Oceanography 2007 in Review".

Colbourne, E.B., M. Stein, M. Ribergaard, B. Petrie, R. Hendry, G. Maillet, G. Harrison, and M. Taylor. 2008. The 2007 NAFO annual ocean climate status summary for the Northwest Atlantic. Standing Comm. on Fish. Environ. (Only electronic version available: http://www.nafo.int/science/frames/ecosystem.html)

Cullen, J., A. Hay, H. Ritchie, S. Hartwell, S. Kirchhoff, T. Bowen, M. Dowd, B. Greenan, J. Hamilton, C. Hannah, M. Lewis, W. Perrie, J. Sheng, P. Smith, H. Thomas, and A. Vézina. 2008. The Lunenburg Bay project, CMOS Bull. SCMO 36(6): 199-205.

Davies, T.D., and I.D. Jonsen. 2008. Recovery potential assessment of 4VWX cusk (Brosme brosme): Population models. DFO Can. Sci. Advis. Sec. Res. Doc. 2008/028. iv + 33 p.

DFO 2008. Proceedings of the Maritimes Region Science Advisory Process on the Assessment of Scallops (*Placopecten magellanicus*) in Scallop Fishing Area (SFA) 29 West of Longitude 65°30'W. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2008/028. iv + 9 p.

DFO. 2008. 2008 assessment of 4VWX herring. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2008/023. 13 p.

DFO. 2008. Assessment of Georges Bank scallops (*Placopecten magellanicus*). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2008/045. 12 p.

DFO. 2008. Assessment of northern shrimp on the Eastern Scotian Shelf (SFA 13-15). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2008/055. 12 p.

DFO. 2008. Assessment of Nova Scotia (4VWX) snow crab. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2008/020. 22 p.

DFO. 2008. Assessment of scallops (*Placopecten magellanicus*) in Scallop Fishing Area (SFA) 29 west of Longitude 65°30 W. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2008/039. 11 p.

DFO. 2008. Centre for Integrated Aquaculture Science (CIAS), Fisheries and Oceans Canada: Report from the March 26, 2007, CIAS national conference call to discuss prioirty research required within DFO pertaining to sustainable aquaculture production. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2008/010. iv + 32 p.

DFO. 2008. Proceedings of a Conference on Ocean Biodiversity Informatics; 2-4 October 2007. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2008/024. iv + 58 p.

DFO. 2008. Proceedings of the Maritimes Region Science Advisory Process on the Recovery Potential Assessment of Cusk (*Brosme brosme*); 27-29 November 2008. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2008/008. iv + 20 p.

DFO. 2008. Proceedings of the Maritimes Region Science Advisory Process on the Assessment of Spiny Dogfish (*Squalus acanthias*); 14-15 November 2007. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2008/009. iv + 18 p.

DFO. 2008. Proceedings of the Maritimes Region Science Advisory Process on the Assessment of Northern Shrimp on the Eastern Scotian Shelf; 4 December 2007. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2008/014. iv + 19 p.

DFO. 2008. Proceedings of the Maritimes Regional Advisory Process on the Assessment of Bay of Fundy Scallop; 5 December 2007. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2008/017. iv + 15 p.

DFO. 2008. Proceedings of the National Workshop on the Impacts of Seals on Fish Populations in Eastern Canada (Part 1); 12-16 November 2007. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2008/021. iv + 144 p.

DFO. 2008. Proceedings of the Workshop on a Comparison of Australian and DFO Maritimes Approaches to Ecosystem Based Management; 3-5 October 2006. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2008/004. iii + 25 p.

DFO. 2008. Recovery potential assessment for cusk (*Brosme brosme*). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2008/024. 11 p.

DFO. 2008. Recovery potential assessment for inner Bay of Fundy salmon. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2008/050. 34 p.

DFO. 2008. St. Mary's Bay longhorn sculpin (*Myoxocephalus octodecemspinosus*) assessment. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2008/051. 13 p.

DFO. 2008. State of the ocean 2007: Physical oceanographic conditions on the Scotian Shelf, Bay of Fundy and Gulf of Maine. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2008/025. 10 p.

DFO. 2008. Status of basking sharks in Atlantic Canada. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2008/036. 13 p.

DFO. 2008. Workshop on Establishing a CIAS Research Work Plan for Ecosystem-Based Management of Aquaculture; February 28 - March 1, 2007. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2008/011. vi + 77 p.

Gibson, A.J.F., H.D. Bowlby, J.R. Bryan, and P.G. Amiro. 2008. Population viability analysis of inner Bay of Fundy Atlantic salmon with and without live gene banking. DFO Can. Sci. Advis. Sec. Res. Doc. 2008/057. v + 71 p.

Harrison, G., C. Johnson, E. Head, K. Pauley, H. Maass, M. Kennedy, C. Porter, and V. Soukhovtsev. 2008. Optical, chemical and biological oceanographic conditions in the Maritimes regions in 2007. DFO Can. Sci. Advis. Sec. Res. Doc. 2008/044: vi + 60 p.

Hendry, R.M. 2008. Environmental conditions in the Labrador Sea in 2007. Northwest Atl. Fish. Organ. Sci. Counc. Res. Doc. 08/49. 8 p.

Koeller, P, M. Covey, and M. King. 2008. An assessment of the Eastern Scotian Shelf shrimp stock and fishery in 2007 with an outlook for 2008. DFO Can. Sci. Advis. Sec. Res. Doc. 2008/052. vi + 48 p.

Lidgard, D., and W.D. Bowen. 2008. Behavioural interactions between predators and their prey in marine ecosystems. DFO Can. Sci. Advis. Sec. Res. Doc. 2008/032. iii + 18 p.

Miller, R.J. 2008. A sea urchin dive fishery managed by exclusive areas., p. 77-84. *In* R. Townsend, R. Shotton, and H. Uchida [ed.]. Case Studies in Fisheries Self Governance. Food Agric. Org. Fish. Tech. Pap. 204.

Perrie, W. and D. Resio. 2007.* A two-scale approximation for nonlinear energy transfers in observed wave spectra, p. 1-3. *In* V. Swail [ed.]. Proc. 10th International Waves Workshop. (Available on line at http://www.waveworkshop.org/10thWaves/Papers/TSA-nov1-07.pdf)

Petrie, B., R.G. Pettipas, and W.M. Petrie. 2008. Air temperature, sea ice and sea surface temperature conditions off Eastern Canada during 2007. Northwest Atl. Fish. Organ. Sci. Counc. Res. Doc. 08/14. 15 p.

Petrie, B., R.G. Pettipas, and W.M. Petrie. 2008. An overview of meteorological, sea ice and sea-surface temperature conditions off Eastern Canada during 2007. DFO Can. Sci. Advis. Sec. Res. Doc. 2008/016. 42 p.

Petrie, B., R.G. Pettipas, W.M. Petrie, and V.V. Soukhovtsev. 2008. Physical oceanographic conditions on the Scotian Shelf and in the Eastern Gulf of Maine during 2007. DFO Can. Sci. Advis. Sec. Res. Doc. 2008/017. 47 p.

Petrie, B., R.G. Pettipas, W.M. Petrie and V.V. Soukhovtsev. 2008. Physical oceanographic conditions on the Scotian Shelf and in the eastern Gulf of Maine (NAFO Areas 4V,W,X) during 2007. Northwest Atl. Fish. Organ. Sci. Counc. Res. Doc. 08/13. 29 p.

Smith, S.J., J. Black, B.J. Todd, V.E. Kostylev, and M.J. Lundy. 2008. The impact of commercial fishing on the determination of habitat associations of sea scallops. Int. Counc. Explor. Sea. C.M.2008/G:08. 21 p.

Smith, S.J., M.J. Lundy, J. Tremblay, C. Frail and S. Rowe. 2008. Scallop Fishing Area 29: Stock status and update for 2008. DFO Can. Sci. Advis. Sec. Res. Doc. 2008/033. iv + 45 p.

Smith, S.J., S. Rowe, and M.J. Lundy. 2008. Scallop production areas in the Bay of Fundy: Stock status for 2007 and forecast for 2008. DFO Can. Sci. Advis. Sec. Res. Doc. 2008/002. vi + 110 p.

TRAC. 2008. Eastern Georges Bank cod. Transbound. Resour. Assess. Comm. Stat. Rep. 2008/01. 6 p.

TRAC. 2008. Eastern Georges Bank haddock. Transbound. Resour. Assess. Comm. Stat. Rep. 2008/02. 6 p.

Tremblay, M.J., S.J. Smith, B.J. Todd, and P.M. Clement. 2008. Associations of lobsters (*Homarus americanus*) off southwestern Nova Scotia with bottom type from images and geophysical maps. ICES C.M.2008/G:04. 27 p.

Walsh, S.J. 2008. A review of current studies on scallop rake modifications to reduce groundfish bycatch in the Canadian offshore scallop fishery on Georges Bank. DFO Can. Sci. Advis. Sec. Res. Doc. 2008/050. x + 77 p.

CONFERENCE ABSTRACTS

NRCan

(includes oral presentations)

Brouillette, P., M.C. Williamson, N. Pinet, P. Potter and D. Lavoie. 2008. The Magdalen Island georeferenced database: purpose, design, and applications. Poster, Geological Association of Canada Annual Meeting, Quebec City, May 12-15.

Campbell, D.C., D. Mosher and G. Wach. 2008. Middle Cenozoic depositional processes along the western Scotian Margin. Central Atlantic Conjugate Margins Conference, Dalhousie University, Halifax, Nova Scotia, August 13-15, 2008.

Giles, M.K., D.C. Mosher, D.J.W. Piper, M.R. Nedimovic and G. Wach. 2008. Continental Slope sedimentation models: Laurentian Channel and Halibut Channel Regions, eastern Canada. Central Atlantic Conjugate Margins Conference, Halifax, Nova Scotia, August 13-15, 2008.

Goss, S.J., D.C. Mosher and G. Wach. 2008. Sequence stratigraphic evolution of the Demerara Rise, Suriname, South America: transition from a rifted to passive margin, analogue to the Scotian Slope. Nova Scotia Energy Research and Development Forum, Antigonish, Nova Scotia, May 21-22, Abstract and Poster.

Parrott, D.R., B.J. Todd, J. Shaw, J.E. Hughes-Clarke, J. Griffin, B. MacGowan, M. Lamplugh and T. Webster. 2008. Integration of multibeam bathymetry and LiDAR surveys of the Bay of Fundy, Canada. Oral presentation, Canadian Hydrographic Conference 2008, Victoria, BC.

Potter, D.P. and G.L. Williams. 2008. Geological vignettes from York Redoubt, National Historic Site. Oral Presentation, Atlantic Geoscience Society Colloquium.

Shaw, J. 2008. Application of multibeam bathymetry to geological mapping. Oral presentation, Canadian Hydrographic Conference 2008, Victoria, BC.

Shaw, J. 2008. Update on Geological Survey of Canada activities in Newfoundland and Labrador. Oral presentation, Canada-Newfoundland Committee on Oceans Management meeting, March 31, St. John's, Newfoundland.

Taylor, R.B., G. Manson, D.L. Forbes, D. Frobel and J. Shaw. 2008. Monitoring of shoreline changes in support of coastal zone management and climate change adaptation in Halifax Regional Municipality. Oral presentation, Canadian Coastal Conference 2008.

PRODUCTS 2008

FISHERIES AND OCEANS CANADA
Maritimes Region - Science Branch

Tide Tables:

Canadian tide and current tables. 2008. Vol. 1. Atlantic Coast and Bay of Fundy. Canadian Hydrographic Service, Fisheries and Oceans, 615 Booth Street, Ottawa, ON K1A 0E6, Canada.

Canadian tide and current tables. 2008. Vol. 2. Gulf of St. Lawrence. Canadian Hydrographic Service, Fisheries and Oceans, 615 Booth Street, Ottawa, ON K1A 0E6, Canada.

Canadian tide and current tables. 2008. Vol. 3. St. Lawrence River and Saguenay Fiord. Canadian Hydrographic Service, Fisheries and Oceans, 615 Booth Street, Ottawa, ON K1A 0E6, Canada.

Canadian tide and current tables. 2008. Vol. 4. Arctic and Hudson Bay. Canadian Hydrographic Service, Fisheries and Oceans, 615 Booth Street, Ottawa, ON K1A 0E6, Canada.

Canadian tide and current tables. 2008. Vol. 5. Juan de Fuca Strait and Strait of Georgia. Canadian Hydrographic Service, Fisheries and Oceans, 615 Booth Street, Ottawa, ON K1A 0E6, Canada.

Canadian tide and current tables. 2008. Vol. 6. Discovery Passage and West Coast of Vancouver Island. Canadian Hydrographic Service, Fisheries and Oceans, 615 Booth Street, Ottawa, ON K1A 0E6, Canada.

Canadian tide and current tables. 2008. Vol. 7. Queen Charlotte Sound to Dixon Entrance. Canadian Hydrographic Service, Fisheries and Oceans, 615 Booth Street, Ottawa, ON K1A 0E6, Canada.

Sailing Directions. 2008. ATL 100. General information Atlantic coast. Canadian Hydrographic Service, Fisheries and Oceans, 615 Booth Street, Ottawa, ON K1A 0E6, Canada.

Sailing Directions. 2008. ATL 102. Newfoundland east and south coasts Cape Bonavista to Ferryland Head (including Placentia Bay). Canadian Hydrographic Service, Fisheries and Oceans, 615 Booth Street, Ottawa, ON K1A 0E6, Canada.

Sailing Directions. 2008. ATL 108. Gulf of St. Lawrence (southwest portion). Canadian Hydrographic Service, Fisheries and Oceans, 615 Booth Street, Ottawa, ON K1A 0E6, Canada.

Sailing Directions. 2008. ATL109. Gulf of St. Lawrence (northeast portion). Canadian Hydrographic Service, Fisheries and Oceans, 615 Booth Street, Ottawa, ON K1A 0E6, Canada.

Canadian Hydrographic Service Charts – 2008:

Chart No. 4587. Mortier Bay. (New Edition)
Chart No. 4848. Holyrood and/et Long Pond. (New Edition)
Chart No. 5056. Khikkertarsoak North Island to/à Morhardt Point. (New Chart)

S57 ENCs (Electronic Navigational Charts) – 2008

CA376295.	Chart 4374.	Red Point to Guyon Island. (New Edition)
CA576110.	Chart 4234.	Port Bickerton. (New Edition)
CA376669.	Chart 5056.	Khikkertarsoak North Island to/à Morhardt Point. (New Chart)
CA376075.	Chart 4817.	Bay Bulls to/à St. Mary's Bay. (New Edition)
CA476672.	Chart 5056.	Hebron Harbour. (New Chart)
CA476670.	Chart 5056.	Moss Harbour. (New Chart)
CA476671.	Chart 5056.	Winnie Bay. (New Chart)
CA376015.	Chart 4846.	Motion Bay to/à Cape St Francis. (New Edition)
CA576010.	Chart 4237.	Sambro Harbour. (New Edition)
CA376083.	Chart 4236.	Taylors Head to/à Shut-In Island. (New Edition)
CA576548.	Chart 4342.	North Head Wharves. (New Edition)
CA476131.	Chart 4909.	Richibucto Harbour. (New Edition)
CA276236.	Chart 4520.	Cape St. John to Cape Bonavista. (New Edition)
CA576222.	Chart 4308.	Petit-De-Gras Inlet. (New Edition)
CA276801.	Chart 4012.	Yarmouth to/à Halifax. (New Edition)

CA276241.	Chart 4010.	Bay of Fundy (Inner Portion). (New Edition)
CA476520.	Chart 4619.	Paradise Sound. (New Edition)
CA476089.	Chart 4236.	Ship Harbour. (New Edition)
CA476084.	Chart 4236.	Approaches to/Approches à Sambro Harbour. (New Edition)
CA576001.	Chart 4201.	Halifax Harbour - Bedford Basin. (New Edition)
CA276367.	Chart 4255.	Georges Bank/Banc de Georges- Eastern Portion/Partie Est. (New Edition)
CA476127.	Chart 4909.	Buctouche Harbour. (New Edition)
CA576003.	Chart 4202.	Halifax Harbour - Point Pleasant to/à Bedford Basin. (New Edition)
CA576115.	Chart 4848.	Holyrood. (New Edition)
CA576546.	Chart 4342.	Long Island Bay. (New Edition)
CA576004.	Chart 4202.	Ocean Terminals. (New Edition)
CA276271.	Chart 4022.	Cabot Strait and Approaches, Scatarie Island to Anticosti Island. (New Edition)
CA576114.	Chart 4848.	Long Pond. (New Edition)
CA476069.	Chart 4233.	Whitehead Harbour. (New Edition)
CA376212.	Chart 5143.	Lake Melville. (New Edition)
CA376819.	Chart 5135.	Approaches to/Approches à Hamilton Inlet. (New Chart)
CA376820.	Chart 5135.	Approaches to/Approches à Hamilton Inlet. (New Chart)
CA476105.	Chart 4210.	Cape Sable to/à Pubnico Harbour. (New Edition)
CA576527.	Chart 4281.	Canso Harbour and Inner Approaches. (New Edition)
CA376045.	Chart 4240.	Liverpool Harbour to/à Lockeport Harbour. (New Edition)
CA276204.	Chart 4013.	Halifax to/à Sydney. (New Edition)
CA576118.	Chart 4848.	Holyrood (Marina). (New Edition)
CA576116.	Chart 4848.	Ultramar (Wharf/Quai). (New Edition)
CA576117.	Chart 4848.	Generator Plant (Wharf)/Centrale d'energie (Quai). (New Edition)
CA176140.	Chart 4003.	Cape Breton to/à Cape Cod. (New Edition)
CA576088.	Chart 4885.	Port Harmon. (New Edition)
CA376135.	Chart 4842.	Cape Pine to/au Cape St Mary's. (New Edition)
CA376278.	Chart 4279.	Bras d'Or Lake-East Bay. (New Edition)
CA576122.	Chart 4847.	Portugal Cove. (New Edition)
CA576177.	Chart 4460.	Charlottetown Harbour. (New Edition)
CA476006.	Chart 4396.	Annapolis Basin. (New Edition)
CA576039.	Chart 4209.	Shelburne Harbour. (New Edition)
CA176030.	Chart 4001.	Gulf of Maine to Strait of Belle Isle/au Detriot de Belle Isle. (New Edition)
CA476179.	Chart 4466.	Hillsborough Bay. (New Edition)
CA476285.	Chart 4306.	Canso Lock to St. Georges. (New Edition)
CA576082.	Chart 4839.	Come By Chance and/et Arnold's Cove. (New Edition)
CA576343.	Chart 4524.	Botwood Wharves. (New Edition)
CA476085.	Chart 4885.	Port Harmon and Approaches/et les Approches Port Harmon. (New Edition)
CA476802.	Chart 4863.	Bacalhao Island to Black Island. (New Edition)
CA376596.	Chart 5133.	Domino Point to Cape North. (New Edition)
CA576603.	Chart 4847.	Bay Roberts. (New Edition)
CA576013.	Chart 4116.	Musquash Harbour. (New Edition)
CA476125.	Chart 4912.	Miramichi. (New Edition)
CA476300.	Chart 4617.	Red Island to Pinchgut Point. (New Edition)
CA576130.	Chart 4909.	Quai/Wharf Pointe du Chêne. (New Edition)
CA376047.	Chart 4241.	Lockeport to/à Cape Sable. (New Edition)
CA476079.	Chart 4839.	Head of/Fond de Placentia Bay. (New Edition)
CA276800.	Chart 4012.	Yarmouth to/à Halifax. (New Edition)
CA376109.	Chart 4234.	Country Island to/à Barren Island. (New Edition)
CA476328.	Chart 4597.	Bay of Exploits - Sheet III (South). (New Edition)
CA276515.	Chart 8011.	Grand Bank/Grand Banc, Northern Portion/Partie Nord. (New Edition)
CA576283.	Chart 4306.	Point Tupper to/à Ship Point. (New Edition)
CA476804.	Chart 4863.	Bacalhao Island to Black Island. (New Edition)
CA576100.	Chart 4266.	Sydport. (New Edition)
CA576098.	Chart 4266.	Sydney River. (New Edition)
CA576185.	Chart 4652.	Humber Arm, Meadows Point to Humber River. (New Edition)
CA476279.	Chart 4530.	Hamilton Sound, Eastern Portion/Patie Est. (New Edition)
CA576021.	Chart 4245.	Yarmouth Wharves/Quais. (New Edition)
CA476126.	Chart 4912.	Miramichi River. (New Edition)
CA576386.	Chart 4846.	St. John's Harbour. (New Edition)
CA376597.	Chart 5133.	Table Harbour. (New Edition)
CA476068.	Chart 4233.	Tor Bay. (New Edition)
CA276091.	Chart 4047.	St. Pierre Bank/Banc De Saint-Pierre to/au Whale Bank/Banc De La Baleine. (New Edition)
CA276652.	Chart 5024.	Nanaksaluk Island to/à Cape Kiglapait. (New Edition)

CA576020.	Chart 4245.	Yarmouth Harbour and Approaches/et Les Approches Yarmouth Wharves/Quais. (New Edition)
CA576096.	Chart 4266.	International Piers. (New Edition)
CA376248.	Chart 4403.	East Point to Cape Bear. (New Edition)
CA476215.	Chart 4728.	Epinette Point to Terrington Basin. (New Edition)
CA376061.	Chart 4227.	Country Harbour to/au Ship Harbour. (New Edition)
CA476081.	Chart 4839.	Head of/Fond de Placentia Bay. (New Edition)
CA176290.	Chart 5001.	Labrador Sea/Mer de Labrador. (New Edition)
CA576280.	Chart 4530.	Carmanville. (New Edition)
CA376242.	Chart 4462.	St. George's Bay. (New Edition)
CA576342.	Chart 4524.	Botwood Harbour. (New Edition)
CA476218.	Chart 4724.	Ticorolak Island to Carrington Island. (New Edition)
CA576282.	Chart 4306.	Canso Lock and Causeway. (New Edition)
CA376230.	Chart 4321.	Cape Canso to Liscomb Island. (New Edition)
CA276286.	Chart 4023.	Northumberland Strait. (New Edition)
CA276514.	Chart 8010.	Grand Bank/Grand Banc Southern. (New Edition)
CA576099.	Chart 4266.	Sydney Wharves/Quais. (New Edition)
CA376330.	Chart 4340.	Grand Manan. (New Edition)
CA576064.	Chart 4277.	Entrance to/Entrée à Great Bras d'Or. (New Edition)
CA576629.	Chart 4519.	Maiden Arm, Spring Inlets and Approaches. (New Edition)
CA476141.	Chart 4278.	Great Bras d'Or and/et St. Patricks Channel. (New Edition)
CA376018.	Chart 4243.	Tusket Islands to/au Cape St Mary's. (New Edition)
CA376355.	Chart 5134.	Approaches to Cartwright, Black Island to Tumbledown Dick Island. (New Edition)
CA476063.	Chart 4277.	Great Bras d'Or, St. Andrews Channel and/et St. Anns Bay. (New Edition)
CA476813.	Chart 4862.	Carmanville to Bacalhoa Island and/et Fogo. (New Edition)
CA576065.	Chart 4277.	Entrance to/Entrée à St. Anns Harbour. (New Edition)
CA576225.	Chart 4587.	Mortier Bay. (New Edition)
CA476281.	Chart 4306.	Strait of Canso and/et Southern Approaches and/et les Approches Sud. (New Edition)
CA476803.	Chart 4863.	Bacalhao Island to Black Island. (New Edition)
CA576200.	Chart 4381.	Chester Harbour. (New Edition)
CA376137.	Chart 4099.	Sable Island/Île de Sable, Western Portion/Partie Ouest. (New Edition)
CA476806.	Chart 4619.	Presque Harbour to Bar Haven Island and/et Paradise Sound. (New Edition)
CA276092.	Chart 4017.	Cape Race to Cape Freels. (New Edition)
CA276477.	Chart 8013.	Flemish Cap/Bonnet Flamand. (New Edition)
CA476327.	Chart 4596.	Bay of Exploits - Sheet II (Middle). (New Edition)
CA376173.	Chart 4622.	Cape St. Mary's to/à Argentia Habour and/et Jude Island. (New Edition)
CA476080.	Chart 4839.	Head of/Fond de Placentia Bay. (New Edition)
CA476273.	Chart 4279.	Lennox Passage. (New Edition)
CA476216.	Chart 5140.	South Green Island to Ticorala Island. (New Edition)
CA576142.	Chart 4278.	Baddeck Harbour. (New Edition)
CA576143.	Chart 4278.	Iona and/et Grand Narrows. (New Edition)
CA476221.	Chart 4308.	St. Peter's Bay to Strait of Canso. (New Edition)
CA476664.	Chart 4384	Pearl Island to/à Cape La Have. (New Chart)
CA276090.	Chart 4045.	Sable Island Bank/Banc de L'Île Sable to/au St Pierre Bank/Banc de Saint-Pierre. (New Edition)
CA476189.	Chart 4385.	Chebucto Head to Betty Island. (New Chart)
CA476196.	Chart 4386.	Head Harbour. (New Chart)
CA476197.	Chart 4386.	Hubbards Cove. (New Chart)
CA576201.	Chart 4381.	Mahone Harbour. (New Edition)
CA576225.	Chart 4587.	Mortier Bay. (New Edition)
CA576226.	Chart 4587.	Mooring Cove Wharves/Quais. (New Edition)
CA576227.	Chart 4587.	Marystown Wharves /Quais. (New Edition)
CA576649.	Chart 4587.	Cow Head Wharves. (New Chart)
CA576042.	Chart 4209.	Lockeport. (New Edition)
CA576121.	Chart 4847.	Bell Island. (New Edition)
CA576124.	Chart 4847.	Port de Grave. (New Edition)
CA576012.	Chart 4116.	Dipper Harbour. (New Edition)

Front cover photo: *Hydrographic survey launches Pipit and Plover have just been deployed by the CCGS Matthew; they are waiting for the multi-beam equipment to come on-line before starting to survey in the Minas Channel, Bay of Fundy, Nova Scotia. The cliffs of Cape Blomidon are visible in the background.*

Photo is courtesy of Michael Lamplugh of the Canadian Hydrographic Service Atlantic at BIO, who was hydrographer-in-charge for this survey.

Back cover photo: *View is of Cape Split from Bennet Bay in the Bay of Fundy; photo was taken in December, 2008.*

Photo is courtesy of Russell Parrott, a geophysicist with the Geological Survey of Canada (Atlantic), Natural Resources Canada, who has been working on high-resolution bathymetric and geophysical surveys to study anthropogenic effects on the marine environment.

Change of address notices, requests for copies, and other correspondence regarding this publication should be sent to:

The Editor, *BIO 2008 in Review*
Bedford Institute of Oceanography
P.O. Box 1006
Dartmouth, Nova Scotia
Canada B2Y 4A2

E-mail address: juryan@nrcan.gc.ca

Cat. No. Fs101-3/2008E
ISBN: 978-1-100-13205-1
ISSN 1499-9951

PDF:
Cat.No. Fs101-3/2008E-PDF
ISBN: 978-1-100-13207-5

Aussi disponible en français

Editor: Judith Ryan

Editorial team: Jane Avery, Pat Dennis, Carolyn Harvie, Judith Ryan

Photographs:
BIO Technographics, the authors, and individuals/agencies credited

Published by:
Fisheries and Oceans Canada and Natural Resources Canada
Bedford Institute of Oceanography
1 Challenger Drive, P.O. Box 1006
Dartmouth, Nova Scotia
Canada B2Y 4A2

BIO website address: www.bio.gc.ca

Government of Canada

Gouvernement du Canada

Fisheries and Oceans Canada

Pêches et Océans Canada

Natural Resources Canada

Ressources naturelles Canada

Environment Canada

Environnement Canada

National Defence

Défense nationale